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SECOND QUARTERLY PROGRESS REPORT, TIMER, NUCLEAR, DELAY

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Prepared by

B. Kunkel

Approved by

Dr. Stanley Grand
Director of Projects

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RADIATION RESEARCH CORPORATION
1114 First Avenue
New York 21, New York

25X1 [redacted]

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CONSULTATION AND COMPONENT DEVELOPMENT IN THE DESIGN AND DEVELOPMENT OF TIMER, NUCLEAR, DELAY

SECOND QUARTERLY PROGRESS REPORT

I. TECHNICAL REQUIREMENTS

A. The timer shall be capable of being externally started, stopped, and be resettable an indefinite number of times.

B. The timer shall have all manually operated controls at the front in order to permit all necessary operations therefrom.

C. The timer shall be capable of being set to a minimum time delay of one (1) day, and be settable in one (1) day increments from one (1) day to three hundred and sixty-five (365) days.

D. A positive safety shall be provided to prevent the timer from functioning for a time delay of less than one (1) day or accidently fired on setting.

E. A visual indication shall be provided to indicate the set time and the time delay remaining when the timer is running.

F. On starting the timer, there shall be a visual indication that the timer is operative.

G. The timer shall have an electrical output capable of initiating a 20,000 erg initiator after runout of the set delay time.

H. The timer shall function with a 90% probability of proper operation with a 90% confidence level in any orientation of the timer and between and including the temperature limits of $0^{\circ}F$ to $110^{\circ}F$.

I. Timing accuracy, i.e., range of extreme timing errors, is desired to be within ±2% and is required to be ±5%.

J. Timer shall be operable and watertight under a pressure of 30 ft., of water.

K. Timer shall have a shelf life of ten (10) years under the environmental conditions specified in the above requirements.

L. The desired overall dimensions shall be 3" x 3" x 6", maximum.

M. The timer shall be capable of being consumed by fire and shattered by an explosive force.

N. The timer shall withstand the transportation vibration test as specified in MIL-STD-303 without detrimental effect to functioning capabilities.

O. Timer shall withstand 5 ft. drop test when dropped on a steel plate (207 Brinell minimum hardness) having a minimum thickness of three (3) inches and solidly supported on a reinforced concrete base.

P. The timer shall be incapable of being detected by noise detecting devices.

II. SUMMARY

During this quarter test circuits were designed for evaluation of the parameters and the components of the timer circuit.

It has been successfully demonstrated by statistical analysis of test data that a high degree of reproducibility can be expected from the final circuit design. The technical requirements state that the timer shall function with a 90% probability of proper operation, and that the range of timing error should be within ± 5%. Evaluation of the data from 21 successive timing cycles produced by a breadboard circuit shows that the probability of a future timing period falling within ± 1.3% of the average time is 99.7%, which is well within the required limits. Results obtained from breadboard circuits are presented to demonstrate the reproducibility of the device and to illustrate some of the circuit design problems.

A series of actuation tests directed towards lowering the energy needed to actuate the Sodeco counter was performed. It was found that by adjusting the armature-to-coil air-gap to .002" - .004", and by properly adjusting the tension on a light spring (as opposed to the usual heavyspring), the mechanical resistance of the counter movements can be minimized. Since the efficiency of utilization of the electrical input power is determined primarily by the design of the counter coil, a series of Sodeco coils, each with a different resistance, was tested. A 10,000 ohm copper coil proved to be the most efficient, and a 13,000 ohm coil containing 300 turns of nickel wire was less efficient. In view of this information, we will obtain special coils wound with many more turns of copper wire, which we believe will significantly decrease the required energy.

A complete exhaust system for manufacturing current regulator tubes and for experimenting with gases and electrodes has been constructed. Trouble-shooting is in progress and tube assembly should begin shortly.

The discharge diodes and voltage regulators have been purchased, and the circuits for testing these are being assembled.

Development of the vacuum tritium batteries is continuing, and several Model R-X2 batteries have been fabricated. No fabrication studies have been done on the 600 uua Model R-2 battery intended for use in the present timer. However, it is expected that the information gained from experimentation with Model R batteries will be directly applicable to R-2 fabrication.

III DISCUSSION OF RESULTS

I. DESIGN PHASE

ITEM I. ANALYZE TECHNICAL REQUIREMENTS

This item has been completed and was discussed in the first quarterly report.

ITEM 2. DESIGN AND SET UP BREADBOARD CIRCUITS AND CONDUCT TESTS

Purpose

Breadboard circuits will be used to test various counter arrangements to evaluate circuit parameters, and to simulate the final circuit.

Status

A. Counter Circuits

The results of counter actuation tests are discussed under Item 3.

B. Timer Test Circuits

In order to evaluate circuit parameters, a breadboard circuit simulating the final timing circuit was set up. An Esterline-Angus recorder was used to record the voltage across the timing capacitor as a function of time. This arrangement yields information concerning:

(1) The repetition rate of the discharge diode firings, (2) the firing and extinction voltages of the diode and (3) the shape of the charging curve.

A schematic diagram of the basic timer circuit test set up, not including the recorder, is shown in Fig. 2-1. Note that the critical components are placed in a desiccator jar. It was found necessary to use the jar to prevent serious electrical leakage paths from developing across the critical components and to ground as a result of room humidity and dust deposits.

The constant current used to charge the capacitor C_t is achieved by using current regulator tubes and battery pack. These CR tubes were made by Radiation Research Corporation under Contract No. DAI-28-017-501-ORD-(P)-1419 and are described in the 9th and

10th quarterly reports. The Esterline-Angus milliameter recorder, which was used later, could not be connected directly across the capacitor because the current drain would be excessive. Therefore both large and small voltages across C_t were measured by using a voltage divider circuit across C_t feeding a D. C. electrometer which in turn feeds a signal to the graphic recorder. In addition, an electrostatic voltmeter was used in order to periodically take voltage checks to compare with the recorder. The revised circuit for measuring and recording the voltage on C_t is shown in Fig. 2-2.

By using a 10^{14} ohm resistor, the current drained by the divider circuit is limited to less than 10 uua at any voltage up to 1000 volts, thus restricting the current drain from the capacitor to about 1% of the 880 uua charging current. The voltage across the electrometer is measured across R_A and is:

$$V_A = \frac{R_A}{10^{14} + R_A} \times V_C$$

, where R_A is the resistance value set on the electrometer.

The electrometer in conjunction with the recorder, in this case, performs two tasks that an electrostatic voltmeter can not; it is able to measure voltages smaller than 300V, and all voltage changes can be recorded.

The resistance R_A of the electrometer is chosen at some convenient value, e.g., 10^{11} or 10^{12} ohms, in order to obtain full scale deflection on a high voltage scale when V_{ct} is at its maximum value of 1000V. The reason for this choice of R_A is that if a smaller resistor is used, the sensitivity of the voltmeter scale has to be increased for full-scale deflection, and stray electrical pick-up interferes with the readings.

Since the current through the divider is limited primarily by the 10^{14} ohm resistor, the current is approximately

$$I = \frac{V_c}{10^{14}}$$

, or for full scale deflection,

$$I = \frac{1000}{10^{14}} = 10 \text{ uua}$$

If $R_A = 10^{11}$ ohms, full scale deflection (Vm) is

$$Vm = I \times R$$

$$= 10(10^{-12}) \times 10^{11} = 1 \text{ volt}$$

For $R_A = 10^{12}$ ohms

$$Vm = 10(10^{-12}) \times 10^{12} = 10 \text{ volts}$$

For the first trial a value of $R_A = 10^{11}$ ohms was chosen. A capacitor (C_A) placed across R_A to damp out pick up was later discarded when the value of $R_A = 10^{12}$ ohms was used and a proper matching obtained to the recorder by the use of a 300 ohm resistor (Fig. 2-2).

In order to make a quick appraisal of the timing circuit, it was decided to set the test cycle at 1 hour. The equation for the timing period is $T = \frac{VC}{I}$ where T is the period, V is the difference between the firing and extinction voltages of the discharge diode, and I is the constant charging current. Therefore, to pick C for a time period of 1 hour, a current of 880 uua, and a voltage V,

$$C = \frac{TI}{V} = \frac{3600 \times 880 \times 10^{-12}}{1000} \doteq .003 \text{ MFD}$$

The complete one hour timing circuit is shown in Fig. 2-3. Several runs were made and the resulting curves for run #1 are shown in Fig. 2-5, where the time between firings is indicated. Standard deviation of the timing periods indicates the reproducibility of this circuit.

Calculation of standard deviation (s.d.):

N = total number of readings
X_i = individual readings
$\overline{X}$ = average of the readings
$\overline{X} - X_i = \delta_i$ = difference between average reading and individual reading

$$\text{s.d.} = \left[\frac{\sum_{1}^{N} \delta_i^2}{N}\right]^{1/2}$$

	X_i Periods	δ_i	δ_i^2
1)	41.0 minutes	.5	.25
2)	41.5	0	0
3)	41.2	.3	.09
4)	41.0	.5	.25
5)	41.2	.3	.09
6)	42.0	.5	.25
7)	41.7	.2	.04
8)	42.0	.5	.25
9)	42.0	.5	.25
	373.6		$1.47 = \sum_1^N \delta_i^2$

Average = 41.5 = $\bar{X}$

$$\text{s.d.} = \sqrt{\frac{1.47}{9}} = \sqrt{.163} = \pm .40 \text{ minutes}$$

3 (s.d.) = ± 1.2 minutes

The significance of the 3 s.d. value lies in the fact that for normal (Gaussian) distributions, 99.7% of all values will be within ± 3 s.d. of the average value. Therefore, the above results indicate that 99.7% of all timing cycles will fall within ± 3% of the average time inherent in this particular combination of components.

Run #2 (Fig. 2-6) shows the effect of removing C_A from across the input to the electrometer. The effect of pick-up is very noticeable. Therefore, at this point there were two problems: 1) the effect of pick up should be eliminated, and 2) the rounding off of the curve after discharge should be corrected so that the extinction voltage could be read.

By putting a 350 ohm resistor across the Esterline Angus, the sensitivity was decreased and the pick up disappeared. Eliminating C_A in the circuit changed the time constant across the electrometer so that its response was almost instantaneous and the extinction part of the curve sharpened noticeably. The effects of these changes are shown in Fig. 2-7 (Run #3).

Some other effects were also noticed. Upon comparing the recorded voltages with those measured with the electrostatic voltmeter directly across the timing capacitor, it was found that the recorded voltage tends to drift upward. This effect was found to be caused by drift in the voltage-division network. The manner in which this drift was corrected is discussed later.

After establishing the circuit with a short timing cycle, another circuit was set up to test the feasibility of a 24 hour cycle. This was accomplished by enlarging the values of the charging capacitor (to .1 mfd) and the current (to 1160 uua).

The curves for the 24 hour run (Run #7) are shown in Fig. 2-8A and 2-8B. Two cycles are shown and the periods obtained were approximately 23 3/4 hours and 24 hours less than 1% from the calculated value indicating very low leakage currents. In addition, the difference in firing times of the two cycles is about 1%.

The portion of the curve that records the extinction voltage shows a residual voltage of about 200 V, after the stylus has reached steady state. Investigation showed conclusively that this residual voltage results from pick up with C shorted. Fig. 2-9 (Pick Up Test Circuit) is a cross-sectional representation of the terminals feeding into the desiccator jar. By application of voltage to point 4 with point 2 grounded, the voltage on the 10 V scale of the electrometer is 2-3 volts (which would correspond to 200 V on the capacitor). However, there is no leakage path for the applied voltage to reach point 6, since the aluminum plate is grounded.

If the 10^{14} ohm resistor is removed from the bell jar and isolated in another shielded bell jar, the pick up is reduced to less than 0.3 volts on the 10 volt scale. The results of isolating the 10^{14} ohm resistor are shown in Run 9, Fig. 2-10, which shows only 30 volts pick up on the discharge curve. However, this arrangement is not too practical because leakage paths across the top of the dessicator jar are increased by high humidity and the voltage across the electrometer increases at a greater rate than expected. (Again the reference voltage increased).

For Run #9, Fig. 2-10, it was decided to use a charging current less than or equal to 900 uua since this value would be approximately the half life of three 600 uua tritium batteries. The current regulators available made a value of 880 uua convenient.

For,

$$T = 24 \text{ hours}$$
$$I_{CR} = 880 \text{ uua}$$
$$V = 1000 \text{ V}$$
$$C = \frac{TI}{V} = \frac{24 \times 3.6 \times 10^3 \times .88 \times 10^{-9}}{10^3}$$
$$= .076 \text{ ufd approximately or } .08 \text{ ufd}$$

Then, if:

$$C = .08 \text{ ufd}$$
$$I_{CR} = 880 (10^{-12}) \text{ amps}$$
$$V_f = 1025 \text{ V (for one particular diode)}$$
$$T = \frac{VC}{I} = \frac{1.025 (10^3) \times 8(10^{-8})}{.88 (10^{-9})} \times \frac{1}{3.6(10^3)} = 25.9 \text{ hours}$$

This time compares with 26.28 hours as measured on the graph for for the first cycle of Fig. 2-10. Leakage losses account for the chart reading being higher.

In order to eliminate leakage and drift and to obtain a more reliable record of the timing cycle, a new timer test set-up was made. This set-up is complete with the exception of the nuclear batteries and counter and is shown in Fig. 2-14. A Keithley model 220 electrometer with a voltage divider (the 10^{12} and 10^{14} ohm resisters) is hooked-up to measure the voltage across the capacitor. The output of the electrometer drives the Esterline-Angus recorder to provide a permanent record of the voltage wave-form. The apparatus checks the operation of the whole circuit, including the diode. The reason for including the electrometer in the hermetically sealed bell jar was to eliminate the problems mentioned above by providing a constant warm temperature and a dry atmosphere for all components as well as complete shielding.

A sample of the data recorded on the chart is shown in Fig. 2-15. For the two cycles shown, firing and extinction voltages are constant and the pick-up is undetectable.

The results of 28 firings of a new G.E. diode chosen at random show no noticeable difference in the extinction voltage (within recorder resolution), but some variation in the firing voltage.

Table 2-1 is a tabulation of firing times for 28 cycles as recorded by the apparatus shown in Fig. 2-14. If the first seven firings are rejected and a statistical analysis is made of the other 21 firings, one can get an idea of the reproducibility of the circuit. The average time obtained for the 21 firings is

$$\bar{X} = 10.99 \text{ hours}$$

and

$$\text{s.d.} = .046 \text{ hours}$$

so that

$$3 \text{ s.d.} = .138 \text{ hours} = 1.3\%.$$

Therefore, the probability that a future timing period will fall within ± 1.3% of 10.99 hours is 99.7% (because 3 s.d. =99.7% probability level). Circuit adjustments will be made in order to increase the cycle to 24 hours. Continous operation of this apparatus will give additional information regarding timing accuracy and aging effects on the various circuit components.

TABLE 2-1

TIMING PERIODS AS RECORDED BY TEST APPARATUS SHOWN IN FIG.2-14

Diode Firing	ΔTime Hours	Diode Firing	ΔTime Hours
1	- - -	15	11.0
2	14.7	16	11.1
3	14.0	17	11.0
4	18.7	18	10.9
5	14.7	19	10.95
6	14.7	20	10.95
7	13.5	21	11.0
8	11.0	22	11.0
9	11.05	23	11.0
10	10.95	24	10.95
11	10.95	25	11.0
12	11.0	26	11.05
13	10.95	27	11.0
14	10.95	28	11.05
		29	11.05

ITEM 3. PERFORM ACTUATION TESTS, DETERMINE MINIMUM ENERGIES

Purpose

To determine what the energy requirements are for actuating various counters with different capacitors.

Status

A series of actuation tests were conducted during the first quarter, and curves and data are included in that report. Since the Sodeco counter type #TCeF4PE meets the physical and mechanical requirements of the timer, recent actuation tests have been directed toward lowering the energy needed to trigger this counter. Consultation with a Sodeco engineer revealed the fact that the mechanisms of their 10 impulses per second counter and their 25 impulses per second counter are exactly the same, the onlydifference being in the strength of the return spring (the stronger spring being used for 25 impulses per second). However, one spring can not be directly substituted for the other without adjusting the tension by bending the support post. Therefore the counters were prepared for testing by attaching the light spring and adjusting the tension until the armature returned satisfactorily. A method for measuring the tension is being investigated. Adjustment was also made to reduce the air-gap between the armature and the coil to the recommended optimum spacing of .002" - .004".

With the mechanical movements optimized for energy, the efficiency of the electrical input power is determined primarily by the coil design. A series of coils, each with a different resistance, was obtained from Sodeco, and each coil was tested in the counter. Table 2-2 shows the minimum voltage and capacitance necessary to actuate the counter for each coil. The results obtained are summarized in Table 2-2 and plotted in Fig. 2-12. It is easily seen that the 10,000 ohms coil (which has 32,000 turns all copper wire) requires the lowest voltage for a given capacitor, i.e. the lowest energy. The 13,000 ohms coil has 34,000 turns of copper wire and 300 turns of nickel wire, and assuming equal diameters for each set of windings, the nickel resistance is 25% of the total. This value was computed by knowing that an 8,000 ohm copper coil had 28,000 turns:

$$\frac{x}{34{,}000} = \frac{8{,}000}{28{,}000}\ ; \quad x = 9{,}800 \text{ ohms for } 34{,}000 \text{ turns of copper.}$$

9,800 ohms is about 75% of 13,000 ohms. Therefore, the remainder, or 25% of the resistance must be caused by the nickel wire. This figure is, of course, approximate but it shows that the efficiency of the coil is reduced by the addition of nickel which has a resistivity about 5 times greater than copper. The advisability of obtaining special coils with more turns of copper is being considered as this would be one way of decreasing the power requirement.

TABLE 2-2

V-C NECESSARY TO ACTUATE 3 NUMERALS OF SODECO COUNTER
SERIAL NO. 246857, TYPE TCeZ4PE

VOLTS

Capacity mfd	3200 ohm Coil	8000 ohm Coil	10,000 ohm Coil	13,000 ohm Coil
.04			2000	2100
.06			1100	1200
.08	3200	1100	800	850
.09			700	750
.10		750	650	700
.14			480	500
.18			380	410
.20	440	400	350	370
.30	330	300	260	290
.40		240	220	240
.50	220	220	190	220
.60			175	190
.70	180	180	155	175
.80			150	170

Counter was adjusted for using a light spring and a .002" - .004" air-gap.

Another set of actuating data is shown in Table 2-3. Here a heavy spring was used and the counter was actuated with and without a diode in the circuit. These readings are somewhat higher than those taken in Table 2-2, showing the importance of having proper spring tension, and it is quite evident that the diode fails to transfer a considerable percentage of the power. The plot of V vs C is shown in Fig. 2-13.

TABLE 2-3

Minimum voltage to actuate 3 numerals on counter

Heavy spring,
.002" - .004" air-gap
13K Sodeco Counter #246113

Without Diode

.06 mfd	1510 volts
.07	1280
.08	1050
.09	965
.10	825
.11	737
.13	640

With Diode

C	V	Diode
.09 mfd	1210	#42 yellow
	1180	#22 orange
.10	1040	#22 orange
	1100	#40 orange
.11	1005	#22 orange

ITEM 4. ANALYZE RELATIONSHIPS AMONG CHARGING CURRENT, CAPACITY, VOLTAGE AND ENERGY

Purpose

The timing period (T) is governed by the law T = CV/I; therefore, the capacitance (C), the voltage (V), and the current (I) are parameters which must be chosen so that the energy requirement of the circuit is compatible with the various components needed to obtain the correct period.

Status

The basic considerations concerning the circuit parameters were discussed in the First Quarterly Report. Briefly, the problem is that of choosing a capaciter large enough to actuate the counter when discharged through a diode, and at the same time arranging the charging current to produce a 24 hour cycle. Of course, it is desirable to keep the current at a minimum so that the least number of batteries will be needed.

If 1000 volts is usedas the firing voltage, it is seen that a .07 mfd (approximately) capaciter is needed to actuate the counter with a 10,000 ohm coil (refer to curve #1, Fig. 2-12). Now, since the extinction voltage of the diode is about 200 to 300 volts (a rough idea of the extinction voltage can be obtained by comparing the voltage requirement with and without diode in Table 2-2), the minimum voltage at which the counter will be actuated through a diode can be obtained by subtracting 300 V from 1000 V. From curve #1 of Fig. 2-12, the value of capacitance required is .09 mfd. To charge a .09 mfd capacitor to 1000 V from 300 V requires a current of:

$$I = \frac{C_t (V_s - V_{ex})}{T} = \frac{.09 \times 10^{-6} (1000 - 300}{86,400} = 730 \text{ uua}$$

Where I = charging current, C_t = timing capacitor, V_s = Diode firing Voltage, V_{ex} = Diode extinction voltage, and T= time.

Therefore, by choosing a counter withthe optimum coil and proper mechanical adjustment, it is possible to have a timer operating on three 600 uua batteries. If, however, however, a capacitance safety factor of, say, 50% be considered, a capacitor of .135 mfd would be needed, and the respective charging current would be 1095 uua, requiring four batteries.

Since keeping the number of batteries required at a minimum is a prime consideration, methods of decreasing the current requirement have been reviewed. The three variables that can be changed are capacitance, voltage, and time. If the capacitance is decreased, the charging current will be less, but the counter will not actuate unless the voltage is increased, which in turn increases the charging current required. If the voltage is decreased, a larger capacitor is needed to actuate the counter. For example, at approximately 225 volts a .4 mfd capacitor is needed to actuate the counter without a diode. (See Fig 2-12). Under these conditions,

$$I = \frac{CV}{T} \doteq \frac{.4 \times 10^{-6} \times 225}{86,400} = \underline{1020 \text{ uua,}}$$

which still requires four batteries.

The time interval could be lengthened to 48 hours, thereby decreasing the current by 50%. The only draw-back here is the counter which would have to be altered so that it counted by 2's instead of by 1's. Off hand, this does not seem practical.

In analyzing the parameters, an interesting curve develops. Fig. 2-16 is a plot of charging current vs capacitance as computed from curve #2 of Fig. 2-12. Here it is seen that the current reaches a minimum value around .09 - .1 mfd, which means that in order to insure minimum source current, the timing capacitor should be close to .1 mfd. The method of deriving the current curve follows:

Refer to curve #2 of Fig. 2-12. At $C = .1$ mfd, $V = 700$ volts,

Since $I = \frac{CV}{T}$, where $T = 86,400$ seconds,

$$I = \frac{.1 \times 10^{-6} \times 700}{86,400} \doteq 810 \text{ uua}$$

In the same manner the power curve was also plotted on Fig. 2-16, i.e. curve #2 of Fig. 2-12 was used and corresponding values of C and E were substituted in the formula: $W = 1/2CE^2$. The minimum power value occurs when a .4 mfd capacitor is used which is a fairly high value and requires a charging current of 1250 uua. The shapes of the pulses actuating the counter are depicted at several points on the power curve. Below .4 mfd, a sharp pulse occurs and above .4 mfd a broad and flatter pulse occurs. Both of these pulses waste a considerable portion of their energy.

In summary, if our present type counters are used, the minimum charging current, for a 24 hour period, will occur when a .1 mfd capacitor is used and will be something under 800 uua.

Regarding the various components, the two most critical (as discussed in the previous report) are the diode and current regulator. For example, in order to obtain a timing accuracy of 2%, (the desired requirement) we can estimate the accuracy required of the diode and current regulator.

The probable error (ignoring the capacitor is given by:

$$\text{Percent Probable error} = \left((\text{Percent error of diode})^2 + (\text{Percent error of current regulator})^2 \right)^{1/2}$$

If we assume, in light of former experience, that we can make current regulators good to 1%, we find the tolerable diode error to be approximately 1.7%.

ITEM 5. STUDY CHARACTERISTICS OF COMMERCIAL COMPONENTS (Literature).

Purpose:

We will use commercially available components if they meet the requirements, and will make inquiries of various companies. This applies particularly to the voltage regulator (1350 volts), current regulator, and the discharge diode.

Status:

This item has been completed: i.e. technical data from many companies which manufacture special components has been reviewed and evaluated. Voltage regulators and discharge diodes have been purchased, and evaluation tests will be conducted. Current regulators are not readily available so Radiation Research Corporation will develop and fabricate these tubes.

ITEM 6. SELECT CIRCUIT DESIGN

The selection of the final circuit design will depend upon the conclusions arrived at in the analysis described in item 4 above.

ITEM 7. COMPLETE SET OF DESIGN DRAWINGS

a) Current Regulator	See Figs. 2-22, 2-23, 2-24, 2-25
b) Voltage Regulator	See Fig. 2-26
c) Capacitor	See Fig. 2-27
d) Battery	See Fig. 2-28
e) Switch	To date, we have not been able to locate a commercial switch with the desired leakage resistance. Proposals for switch designs are shown in Fig. 2-29.
f) Counter	See Fig. 2-30
g) Discharge Circuit	See Fig. 2-31
h) Circuit	See Fig. 2-32

II. COMPONENT DESIGN

ITEM 1. SURVEY COMMERCIALLY AVAILABLE PARTS.

Status

This was a literature investigation and it has been completed.

ITEM 2. DESIGN TUBES AND ORDER PARTS.

Status

The current regulator tube has been designed and parts have been ordered and received. Assembly will begin as soon as the vacuum system is ready for operation.

ITEM 3. DESIGN EXPERIMENTAL EXHAUST SYSTEM

Status

This design has been completed.

ITEM 4. DESIGN EXHAUST SYSTEM FOR FABRICATING TUBES

Status

Completed.

ITEM 5. CONSTRUCT EXPERIMENTAL EXHAUST SYSTEM

Status

The completion date for this system has been moved from July to August because the initial construction incorporated some parts that had vacuum leaks. The system has been reconstructed and is now undergoing a trouble-shooting procedure to outgas it and to eliminate any detectable leaks.

Fig. 2-21 is a block diagram of the exhaust system. One of the features of the system is the arrangement whereby the bell jar can be replaced by a water-cooled quick-coupling to process finished tubes. Thus, one basic exhaust system is used, and by replacing the top unit, the system can be converted from an experimental set up to a production one.

The special water-cooled quick-coupling was installed so that tubes could be processed by heating with RF without destroying the vacuum-tight "O" ring seal on the tubulation.

Also incorporated in this design is a special gas injector unit with gauge which couples directly to the gas tank and exhaust system, thus eliminating sources of air leaks along the line. This injector is manufactured by the Linde Company for the sole purpose of transferring high purity rare gas from tanks to exhaust systems.

ITEM 6. PERFORM TESTS ON ELECTRODES AND GASES FOR CURRENT REGULATOR TUBE

Status

No work has been started on this item because the exhaust system has not been finished and approved.

ITEM 7. DESIGN AND CONSTRUCT TEST CIRQUITS FOR ALL TUBES AND RUN PRELIMINARY TESTS

Status

A. Current Regulator Test Circuit

To test the operation of the current regulators, the circuit shown in Fig. 2-4 was used. This test is not a rigorous one but rather one of expedience. The CR tubes allow the .001 mfd capacitor to be charged linearly, and subsequently, the voltage across the CR tubes, which is equal to the applied voltage minus the voltage across the capacitor, decreases linearly. By recording the current, as measured by the electrometer and Esterline Angus, and by taking periodic voltage readings across the capacitor to ground, a current-voltage plot can be obtained. The recorded curve for this test is shown in Run #6, Fig.2-11, and it is seen that the tubes chosen had good regulation from 50 to 1350 volts.

The proposed final circuit for testing CR tubes is shown in Fig. 2-17. Before the test begins, SW1 is closed and a known voltage is applied across the CR tube. Simultaneously with opening SW1 a stop-watch is started and the capacitor C is allowed to charge to one volt, as read on the electrometer. If the electrometer has been previously calibrated with a standard cell, and the capacitor measured accurately, the current, I, may be computed by:

$I = \frac{VC}{T}$, when $V = 1$ volt and T equals the time required to charge C to one volt.

This circuit can measure currents with much better than 1% accuracy.

B. Voltage Regulator Test Circuit

Status

Fig. 2-18 shows the test circuit which will be used to test VR tubes. By varying the input voltage, the current through the VR tube can be varied between the limits which are required, and a voltage-current plot can be made.

C. Discharge Diode Test Circuit

Status

The testing of one hundred XD-1000 General Electric diodes has been started. In order to properly appraise these diodes, two tests have been devised in light of the requirements of the timing device:

1. The reproducibility of the firing voltage and the extinction voltage will be tested.
2. The energy transfer capability of the diode will be checked.

The circuit for test 1 is shown in Fig. 2-19. This design evolved from the consideration that the accuracy of the timer depends primarily upon the constancy of the difference in voltage between the firing and extinction voltages of the diode. If either the firing or extinction voltage varies, the diode is useless, and therefore both of these values will be checked simultaneously by merely recording the periods between firings. By statistical analysis, then, it will be possible to determine whether or not a diode is stable and suitable for the timer. Eight diodes can be tested simultaneously, and tests have already begun. More positions will be added to the test set so that it will be possible to obtain information regarding the possible shifting of the diodes' voltages as a result of aging; i.e. it will be important to know whether or not a diode changes its characteristics after it has been fired several hundred times.

Fig. 2-20 is the circuit to be used for measuring the energy transfer of diodes. The diodes tested in this system will have their firing and extinction voltages measured, and the difference between the two voltages will have to be more than the minimum voltage required to actuate the counter with the chosen capacitance.

The circuit will be automatic once it is started, and a buzzer will indicate that the test is completed and that values can be read. The firing voltage will be read on the precision Helipot scale and the deionization voltage will appear on an electrostatic voltmeter. Parts have been ordered for this circuit.

ITEM 8. DESIGN AND CONSTRUCT AGING SET-UP

Status

The primary concern here is the discharge diode, and an aging system will be considered as soon as tests can be run on the tubes to evaluate them.

ITEM 9. SELECT FINAL CR TUBE DESIGN

Status

The present structural design is shown in Fig. 2-22 and the electrical characteristics will be specified at a later date when circuit requirements are known.

ITEM 10. SELECT ALL COMPONENTS

Status

This is scheduled to be completed in December 1958 and will be related to other items in the development schedule.

ITEM 11 ENCLOSURE DESIGN

Status

At a recent meeting with Mr. George Kaye of Picatinny Arsenal on August 12, 1958 it was decided that we would design the enclosure, which must be a hermetically sealed unit. No work has been done on this to date.

III. COMPONENT FABRICATION

Item 1. BUILD EXHAUST SYSTEM TO FABRICATE TUBES

Status

The status of this exhaust system was discussed under Item 5 of Component Design.

ITEM 2. FABRICATE COMPONENTS

Status

The current regulater parts are on hand and assembly will begin in September, as scheduled.

ITEMS 3, 4 and 5 Test CR tubes, diodes and VR tubes.

These items have been discussed elsewhere in this report, and tests will be started as soon as the tubes and test circuits are ready.

ITEM 6. FABRICATION OF NUCLEAR BATTERIES

Status

Development of Vacuum Tritium Batteries under Army Signal Corps Contracts Numbers DA-36-039-SC-78047 and DA-36-039-SC-75980 is continuing. Recent progress includes design and construction of a new high-pumping-speed vacuum system, receipt of fully-assembled ceramic terminals, and fabrication of several Model R-X2 batteries. No fabrication studies have been done on the 600 uua Model R-2 battery intended for use in the present timer. However, it is expected that the information gained from experimentation with Model R batteries will be directlyapplicable to R-2 fabrication. Tentative outline drawing of the Model R-2 battery is shown in Figs. 2-28.

IV. ASSEMBLE TIMERS

All of the items in this phase must await completion of other phases.

IV. DEVELOPMENT SCHEDULE

Revised 8/1/58

The following revisions in the schedule were made:
(Refer to Development Schedule as presented in First Quarterly Report).

I Design Phase, Items 2 and 6.

Item 2 was expanded in scope to include Item 6 because it is more logical to combine test results and design when the items are discussed.

Items 3 and 4. The period for conducting these tests and analysis has been extended to include September because new information was uncovered.

Item 7. The completion date for this item has been moved to September for same reason as given for Items 3 and 4.

II Component Design

Item 5. Because of unanticipated vacuum leakage problems, the completion date was moved to September.

Item 6. It is now evident that testing of gases, etc. will be extended through October.

Item 7. In order to get complete and meaningful data on tubes and circuits, an extended period of time will be needed. Therefore, work will be conducted through December.

Item 8. Although we have scheduled the aging set-up to be completed by October, it may be completed in September.

Item 9. In view of other changes, completion of this item has been changed by one month.

Item 11. Estimated completion by December, 1958.

III Component Fabrication

Item 5. It will be possible to start work on this item earlier than originally planned.

All other items on the schedule have been left unchanged. The complete revised development schedule follows.

RADIATION RESEARCH CORPORATION
DEVELOPMENT SCHEDULE   Revised 7/1/58
Project: 2264
For Year: 1958 - 1959

I   DESIGN PHASE

Item	Description	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May
1	Analyze technical requirements	X											
2	Design and Set-up Bread-board Circuitd & conduct tests	X	X	X	X								
3	Perform Actuation Tests, Determine Minimum Energies	X	X	X	X								
4	Analyze Relationships Charging current, capacity, Voltage and Energy	X	X	X	X								
5	Study Characteristics of Commercial components (Literature)	X	X										
6	Select Circuit Design			X	X								
7	Complete Set of Design Drawings				X	X							
	a. Current Regulator Tube		X	X									
	b. Voltage Regulator Tube			X									
	c. Capacitor			X									

REMARKS:
X = Month during which work will be conducted.
X = Month completed.
X in the June Box indicates completed either during or prior to June, 1958

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RADIATION RESEARCH CORPORATION
DEVELOPMENT SCHEDULE Revised 7/1/58
Project: 2264
For Year: 1958 - 1959

I DESIGN PHASE (Continued)

Item	Description	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May
	d. Battery			⊗									
	e. Switch			X	X	X							
	f. Counter			⊗									
	g. Discharge Diode			⊗									
	h. Circuit				X								

REMARKS:
X = Month during which work will be conducted.
⊗ = Month completed.

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RADIATION RESEARCH CORPORATION
DEVELOPMENT SCHEDULE Revised 7/1/58
Project: 2264
For Year: 1958 - 1959

II COMPONENT DESIGN

Item	Description	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
1	Survey commercially available parts	X											
2	Design tubes and order parts	X											
3	Design experimental exhaust, etc.	X											
4	Design Exhaust System for Fabricating Tubes	X	X										
5	Construct experimental Exhaust system (for C.R.Tube)	X		X	X								
6	Perform Tests on electrodes and gases for CR tube			X	X	X							
7	Design and construct test circuit for tubes and run preliminary tests (all tubes)				X	X	X	X					
8	Design and construct aging set-up			X	X	X							
9	Select final CR tube design						X						
10	Select all components							X					
11	Enclosure design					X	X	X					

RADIATION RESEARCH CORPORATION
DEVELOPMENT SCHEDULE   Revised 7/1/58
Project: 2264
For Year: 1958 - 1959

III   COMPONENT FABRICATION

Item	Description	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May
1	Build Exhaust System to fabricate tubes			X									
2	Fabricate components				X	X	X	X					
3	Test CR tubes for current, regulation				X	X	X	X	X				
4	Test diodes for V_s, pre-break-down current & energy transfer			X	X	X	X	X	X				
5	Test VR tubes						X	X	X				
6	Fabricate Nuclear Batteries					X	X	X	X				

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RADIATION RESEARCH CORPORATION
DEVELOPMENT SCHEDULE Revised 7/1/58
Project: 2264
For Year: 1958 - 1959

IV ASSEMBLE TIMERS

Item	Description	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May
1	Assemble 2 timers								X				
2	Test for accuracy of counting								X	X			
3	Vibration Test (Picatinny Arsenal)									X			
4	Drop Test (Picatinny Arsenal)									X			
5	Water Test (Picatinny Arsenal)									X			
6	Test for accuracy of counting for 1 year (Picatinny Arsenal)									1960 X			

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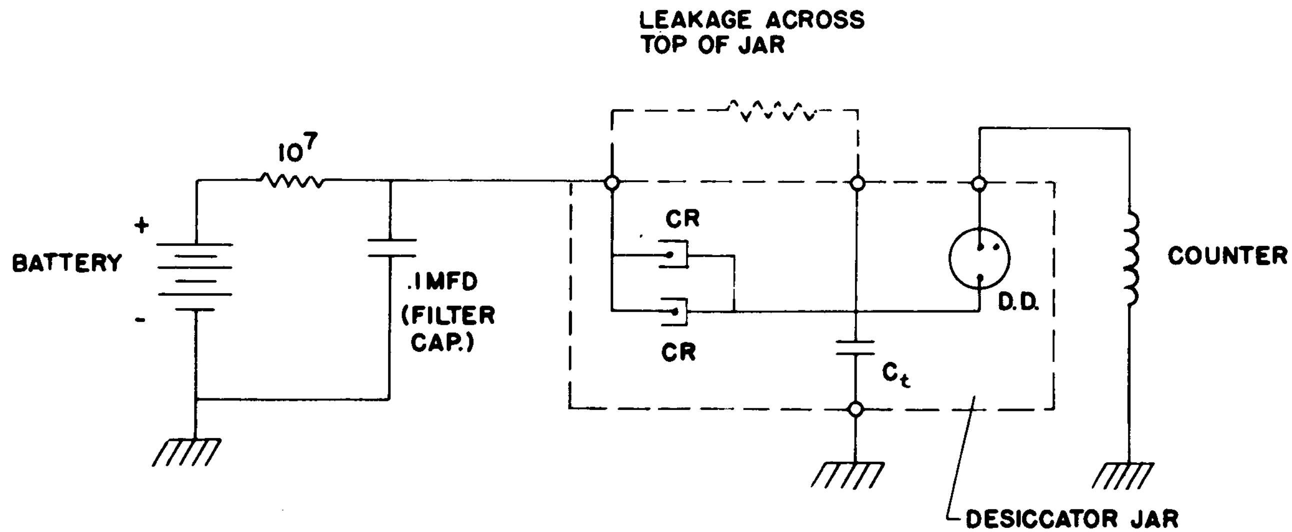

FIG 2-1 BASIC TIMER CIRCUIT TEST SET-UP

DR.NO. 580

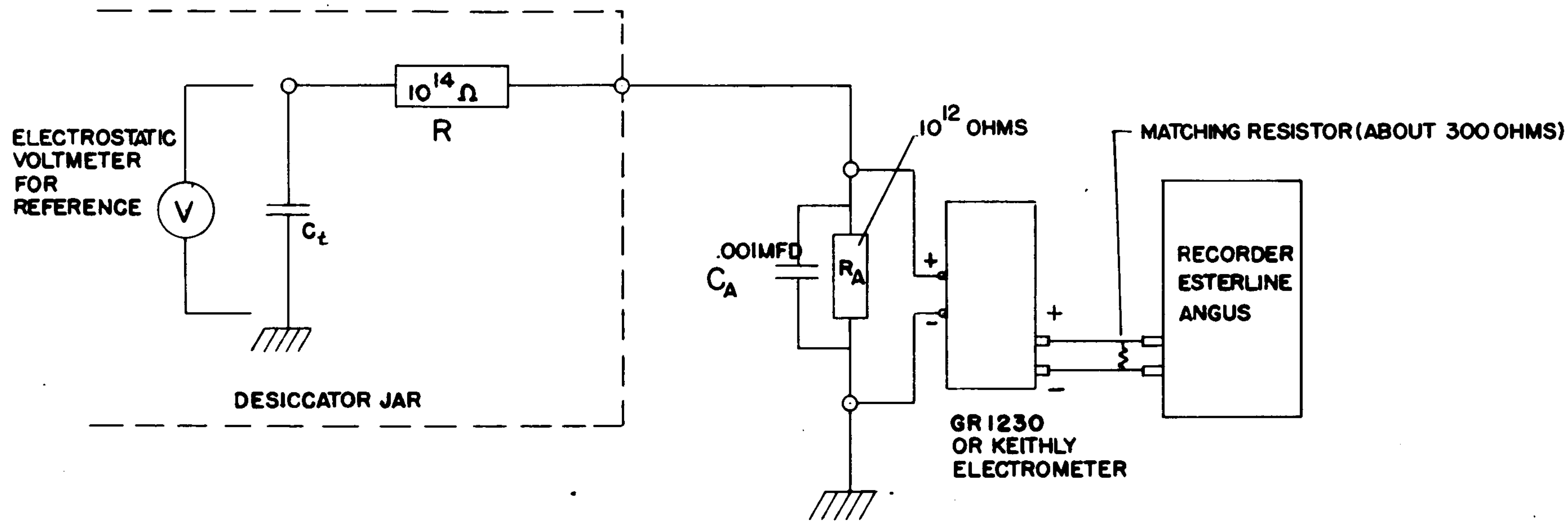

FIG 2-2 TEST CIRCUIT FOR RECORDING CAPACITOR VOLTAGE

DR. NO 581

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DR. NO 582

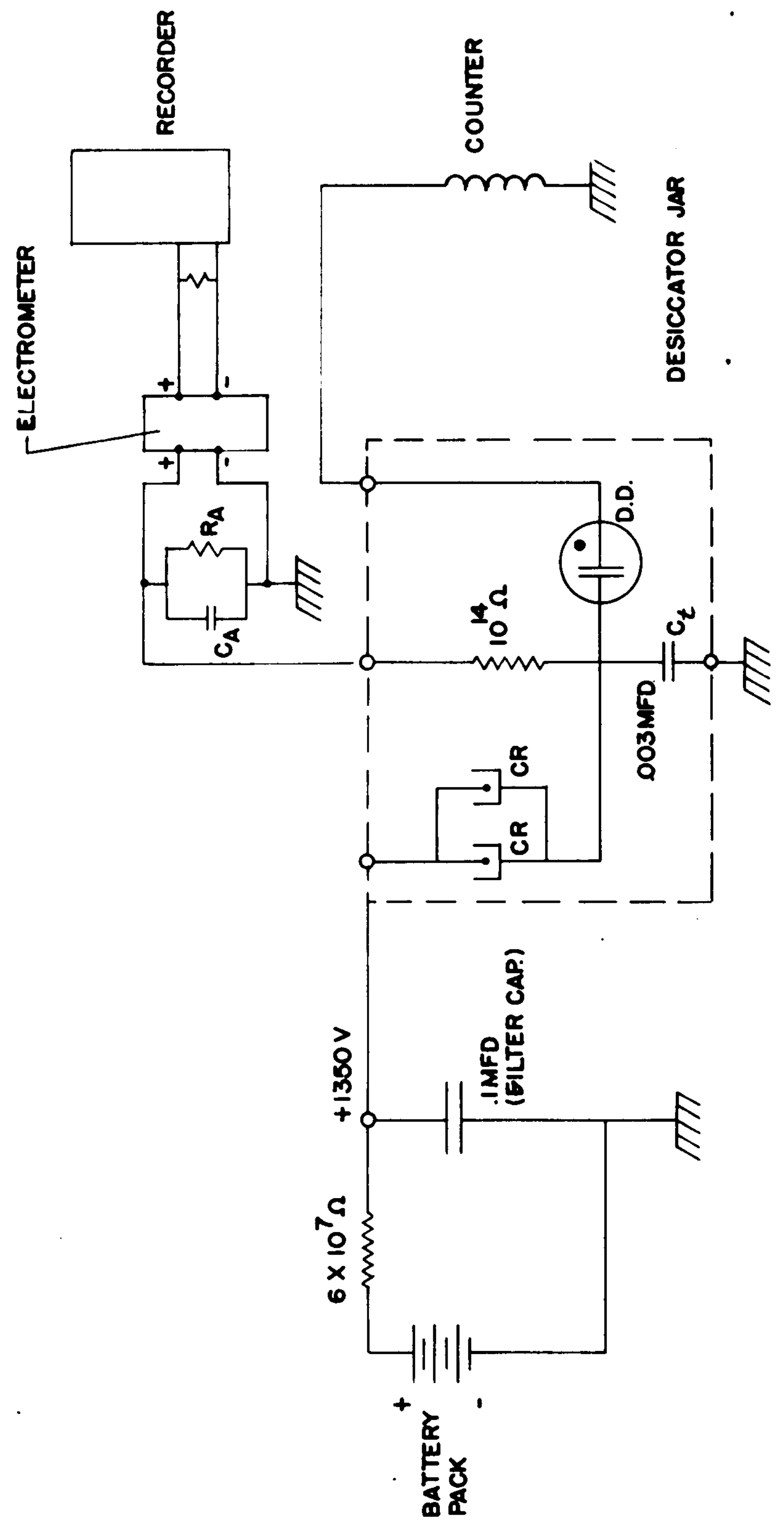

FIG 2-3 ONE-HOUR TIMER CIRCUIT

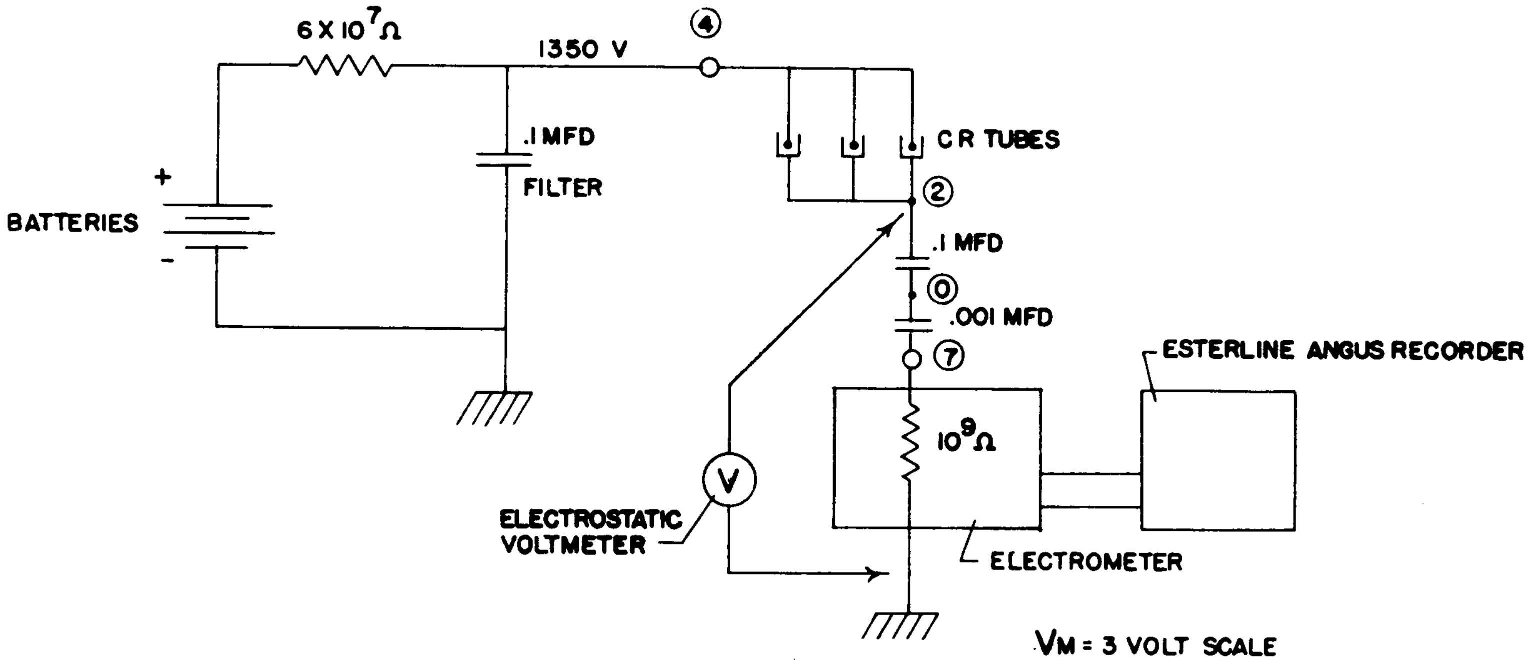

FIG 2-4 CURRENT REGULATOR TEST CIRCUIT FOR RECORDER

DR.NO. 583

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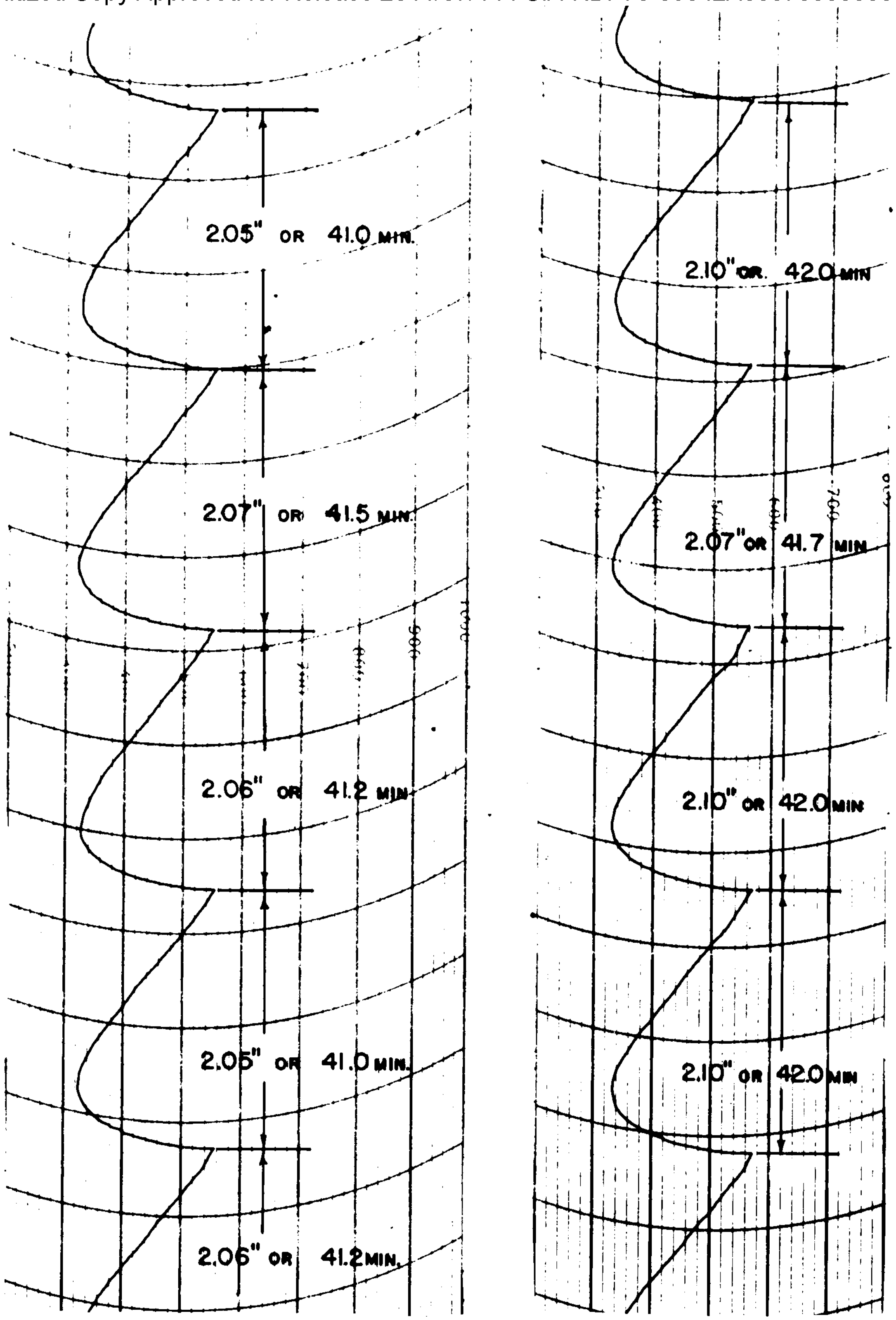
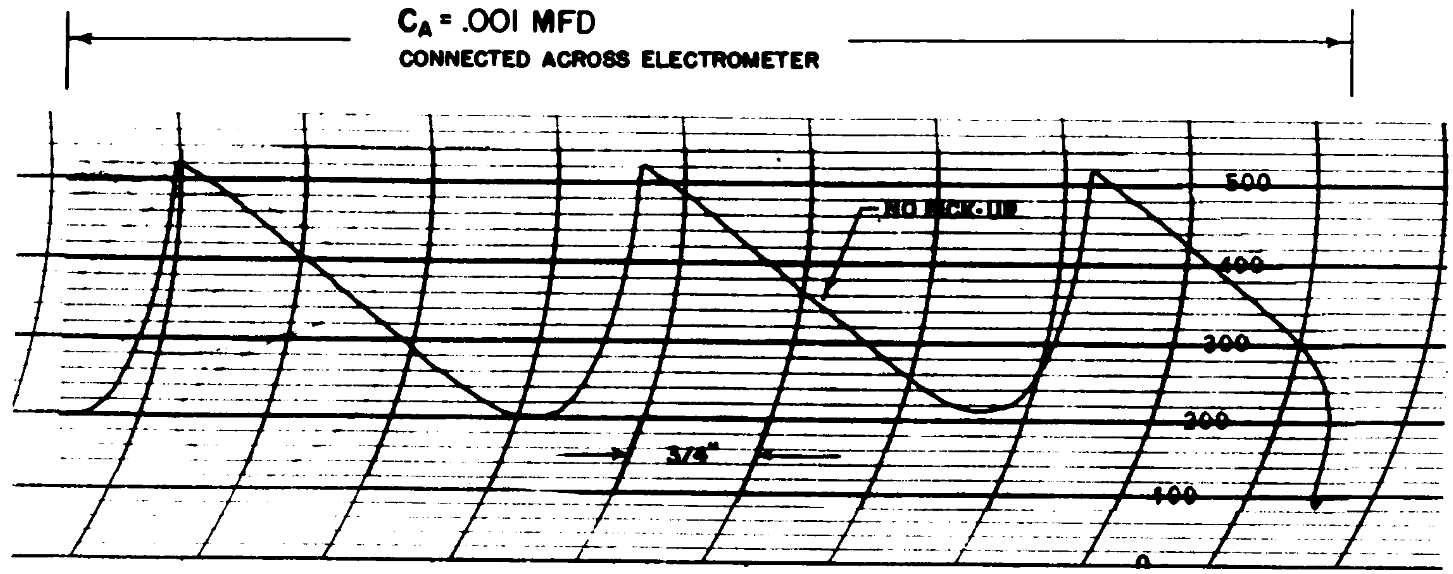


CHART SPEED: 3/4" = 15 MIN. (VERTICAL DISTANCE OF 1 DIVISION)
RUN # 1
DATE 6/18/58
DIODE # 10
C R TUBE A-6, A-7
CHARGING CURRENT 880 µµA
CAPACITOR .003 MFD

TIME = INCHES X 20 MIN.

FIG 2-5 DISCHARGE CURVES OBTAINED FROM CIRCUIT IN FIG 2-3

DR. NO. 569



RUN # 2
SPEED = 3/4" = 1 HOUR
DATE 6-18-58

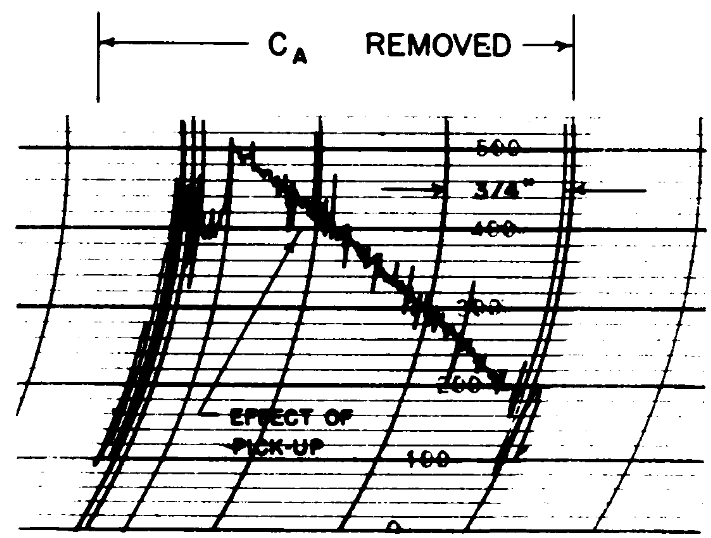
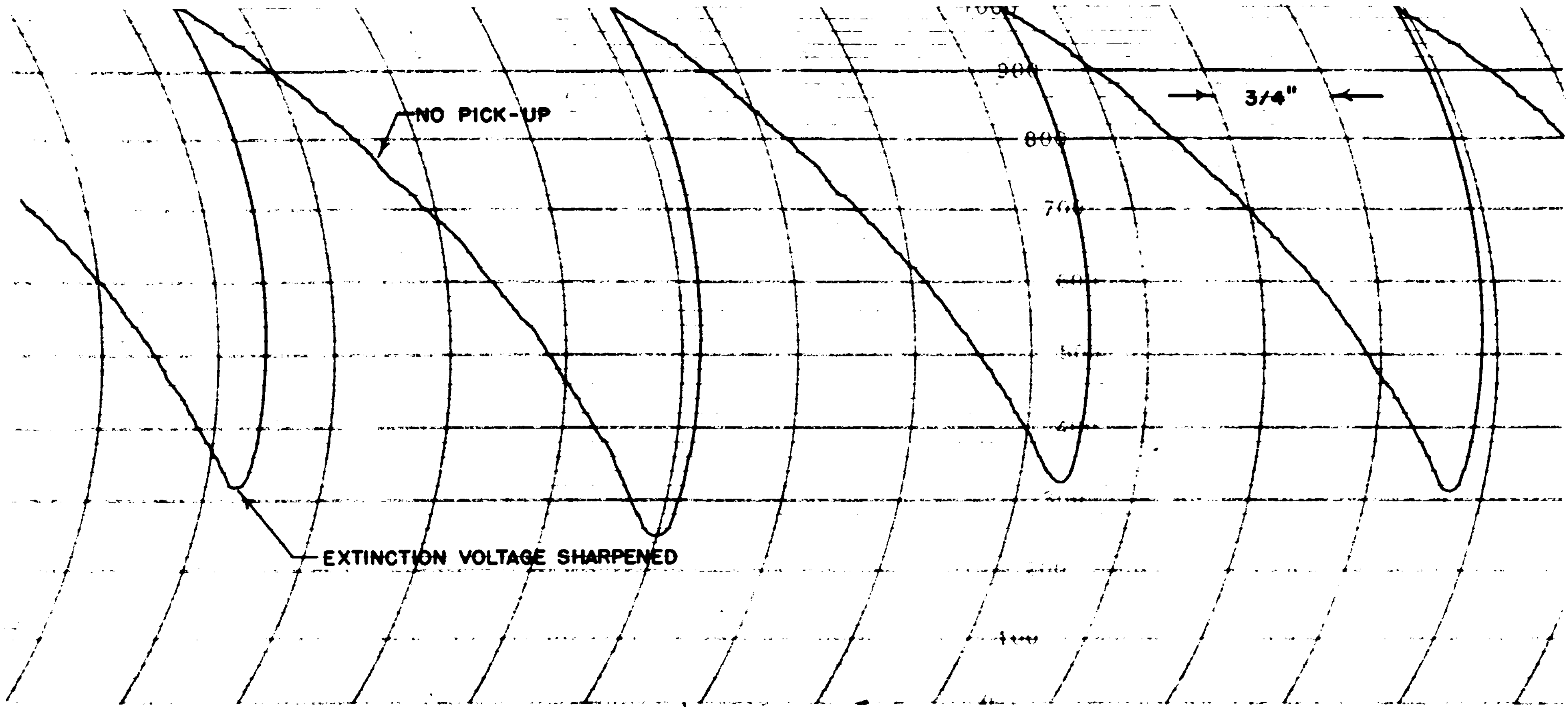


FIG 2-6 EFFECT OF CAPACITANCE ON PICK-UP

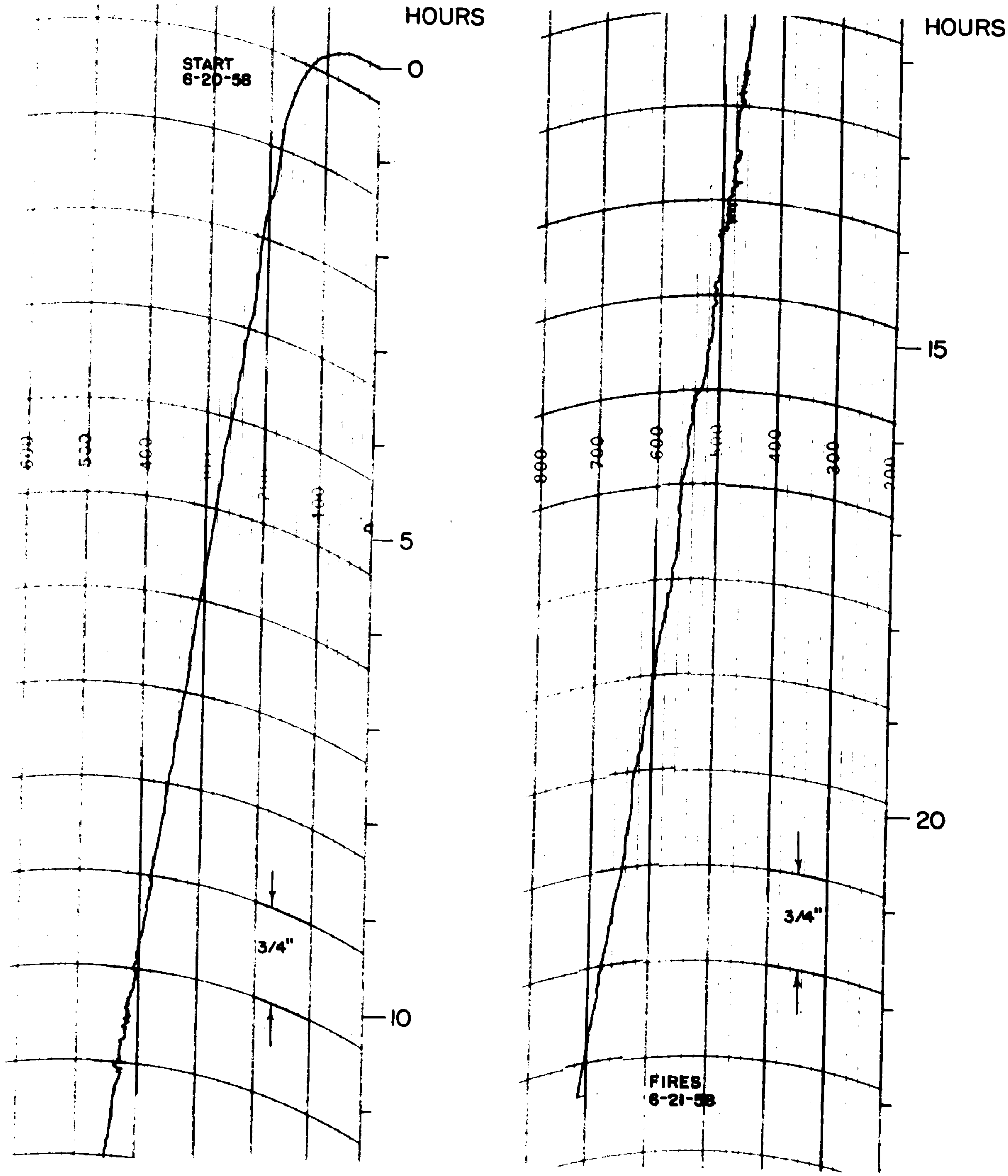
DR.NO.570



RUN # 3
SPEED 3/4" = 15 MIN.
DATE 6-19-58

FIG 2-7 EFFECT OF PUTTING 350 Ω RESISTOR ACROSS ESTERLINE ANGUS AND ELIMINATING C_A.

DR. NO 571

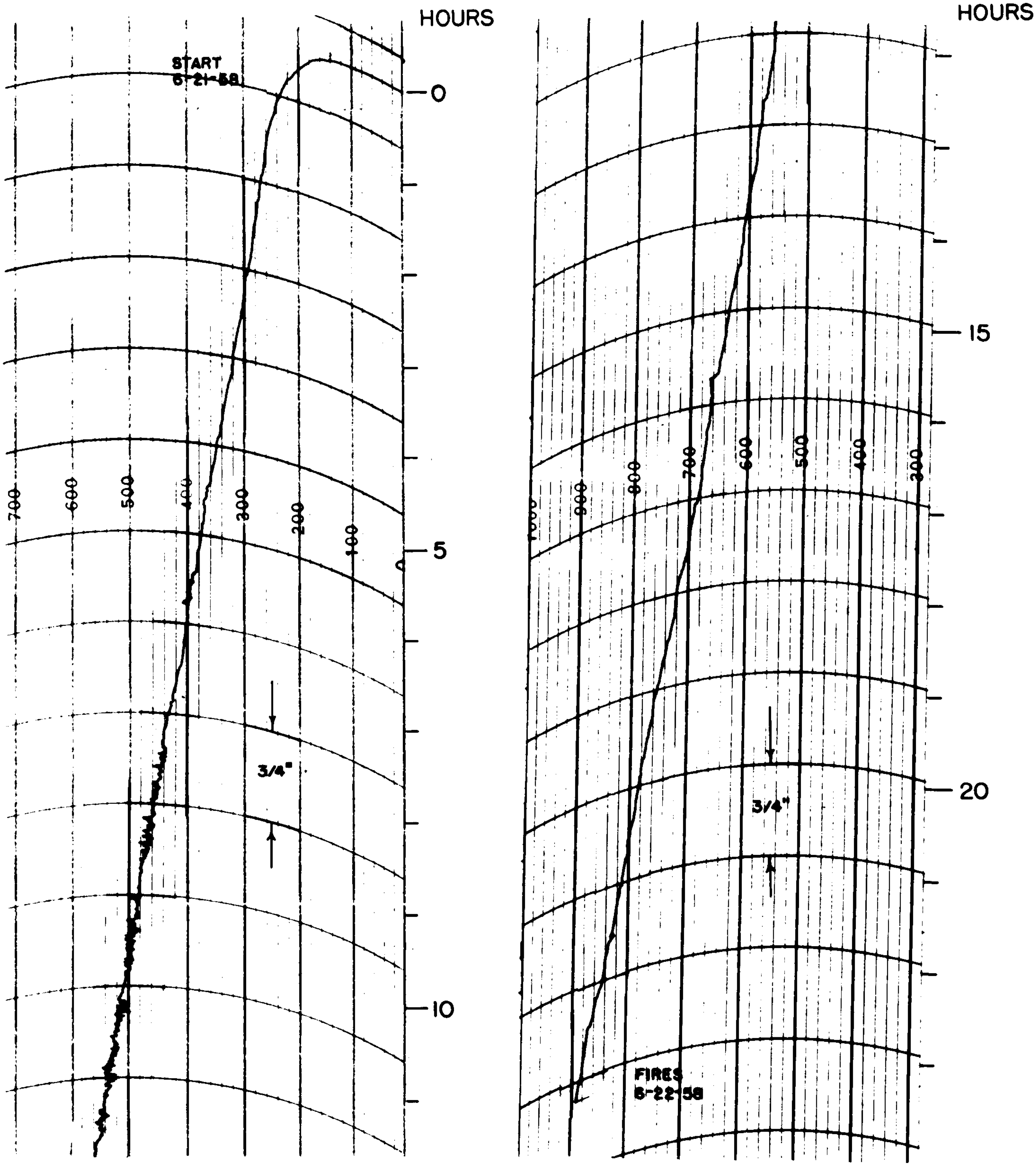


RUN # 7A
DATE 6-20-58 — 6-23-58
SPEED 3/4" = 1 HOUR

CYCLE ≅ 23 3/4 HOURS

FIG 2-8A 24 HOUR DISCHARGE CYCLE

DR. NO. 572



RUN # 7B
DATE 6-20-58 — 6-23-58
SPEED 3/4" = 1 HOUR

FIG 2-8B 24 HOUR DISCHARGE CYCLE

DP NO. 573

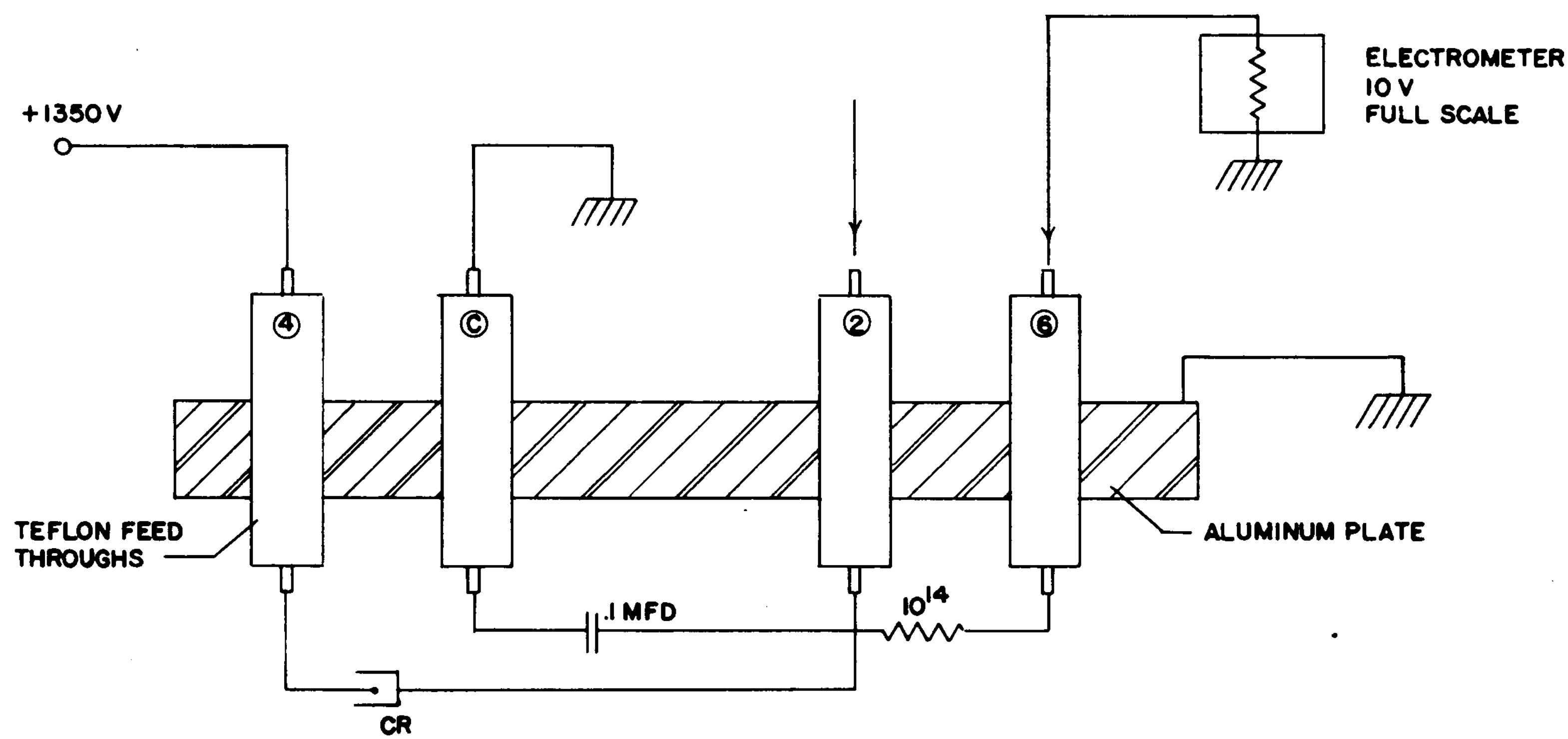


FIG 2-9 PICK-UP TEST CIRCUIT

DR.NO.584

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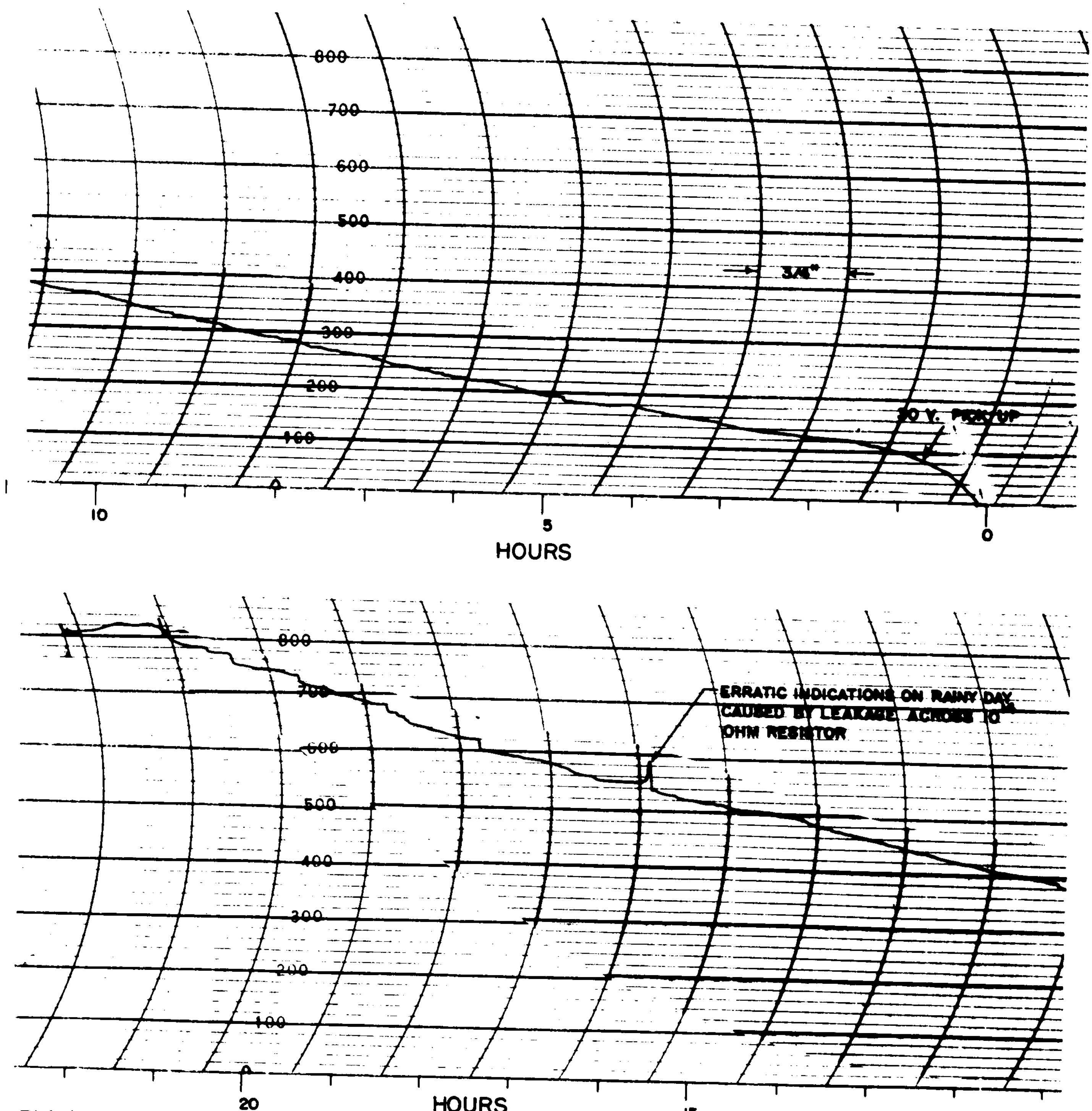
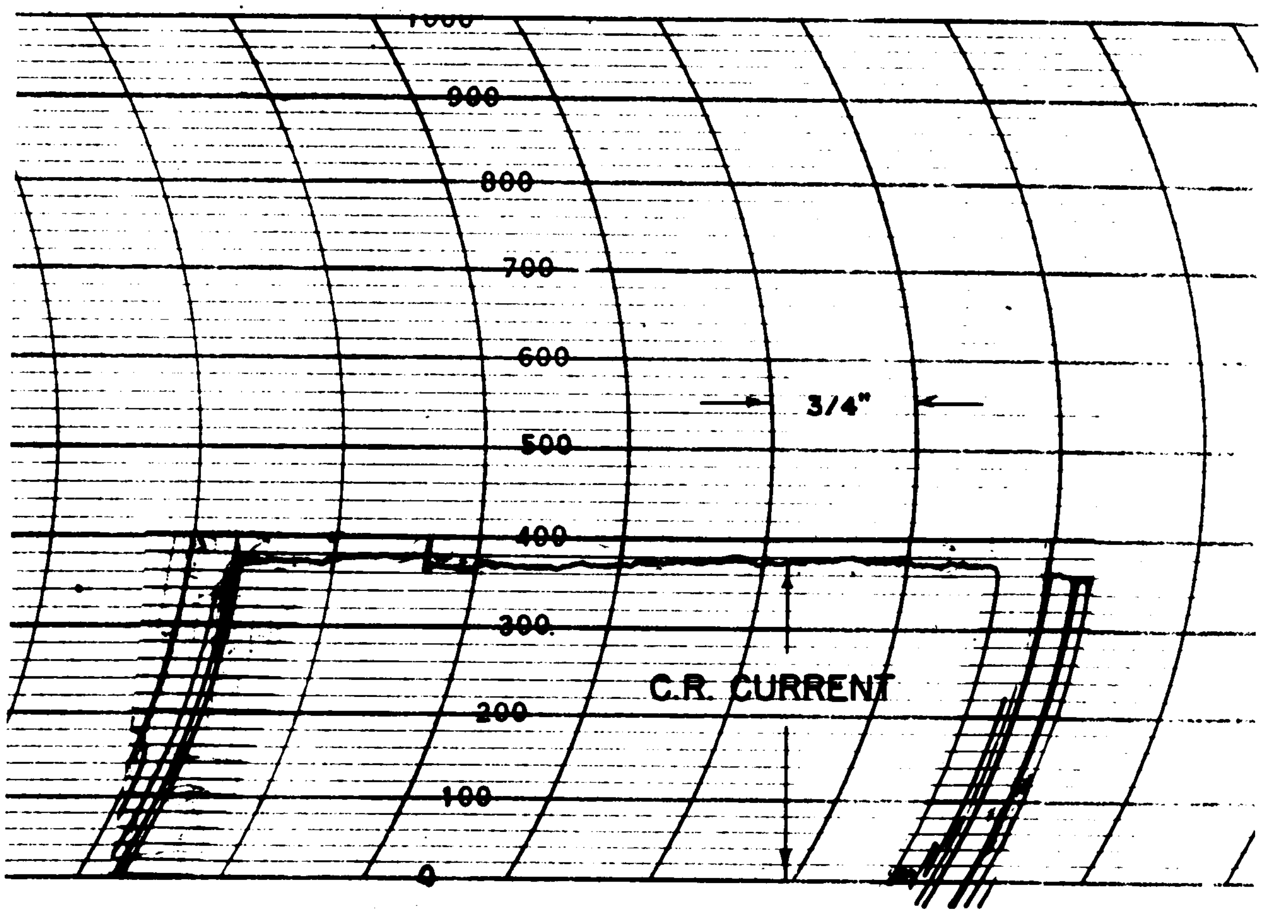


RUN #9
SCALE 3/4" = 1 HOUR
DATE 6-24-58 – 6-26-58

FIG 2-10 10^{14} OHM RESISTOR IN SEPARATE DESICATOR JAR

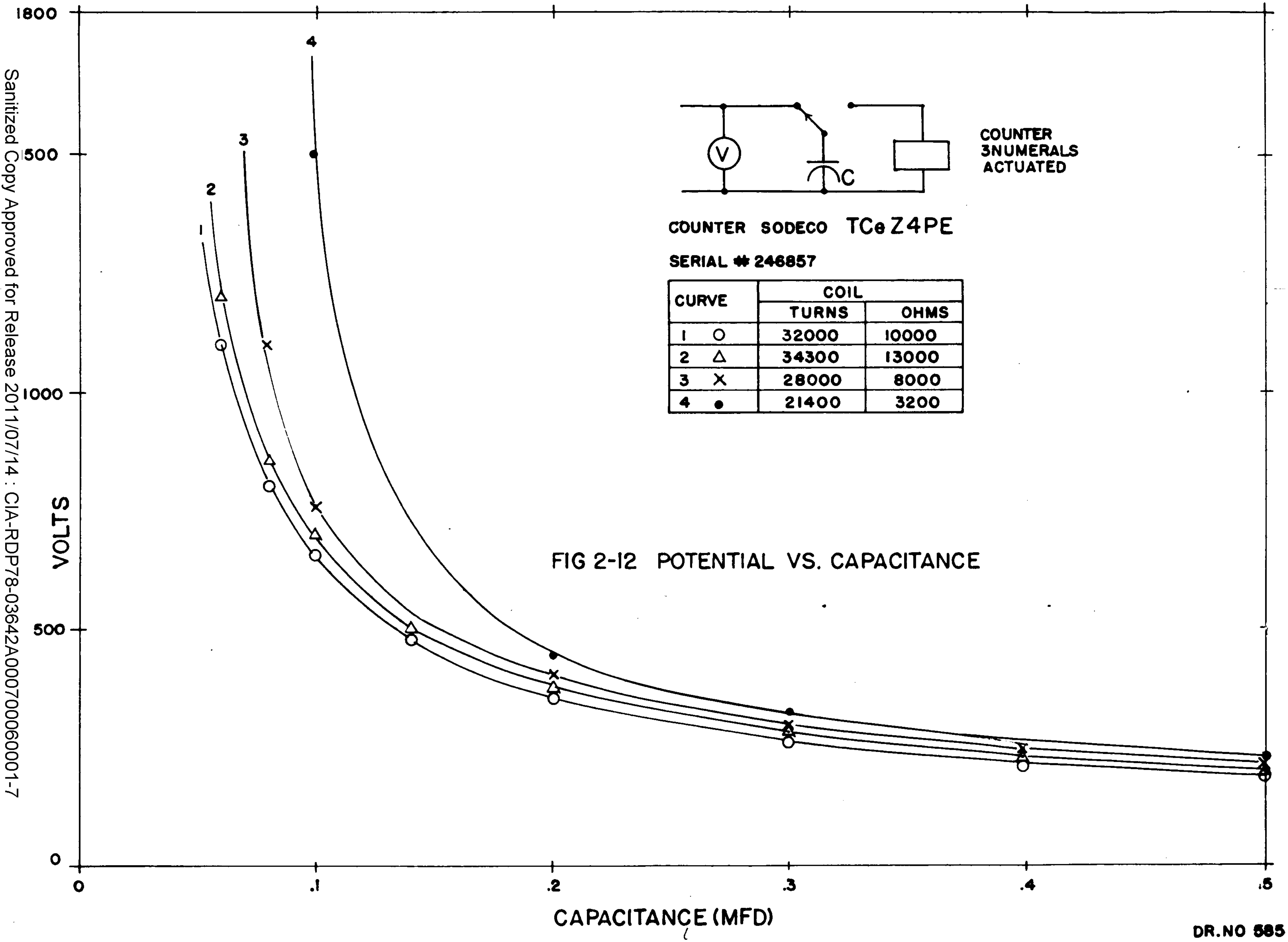
DR. NO 574



RUN # 6
DATE 6-20-58
SPEED 3/4" = 1 HOUR

FIG 2-11 CURRENT REGULATOR CURVE

DR. NO. 575



CURVE		COIL	
		TURNS	OHMS
I	O	32000	10000
2	△	34300	13000
3	X	28000	8000
4	●	21400	3200

FIG 2-12 POTENTIAL VS. CAPACITANCE

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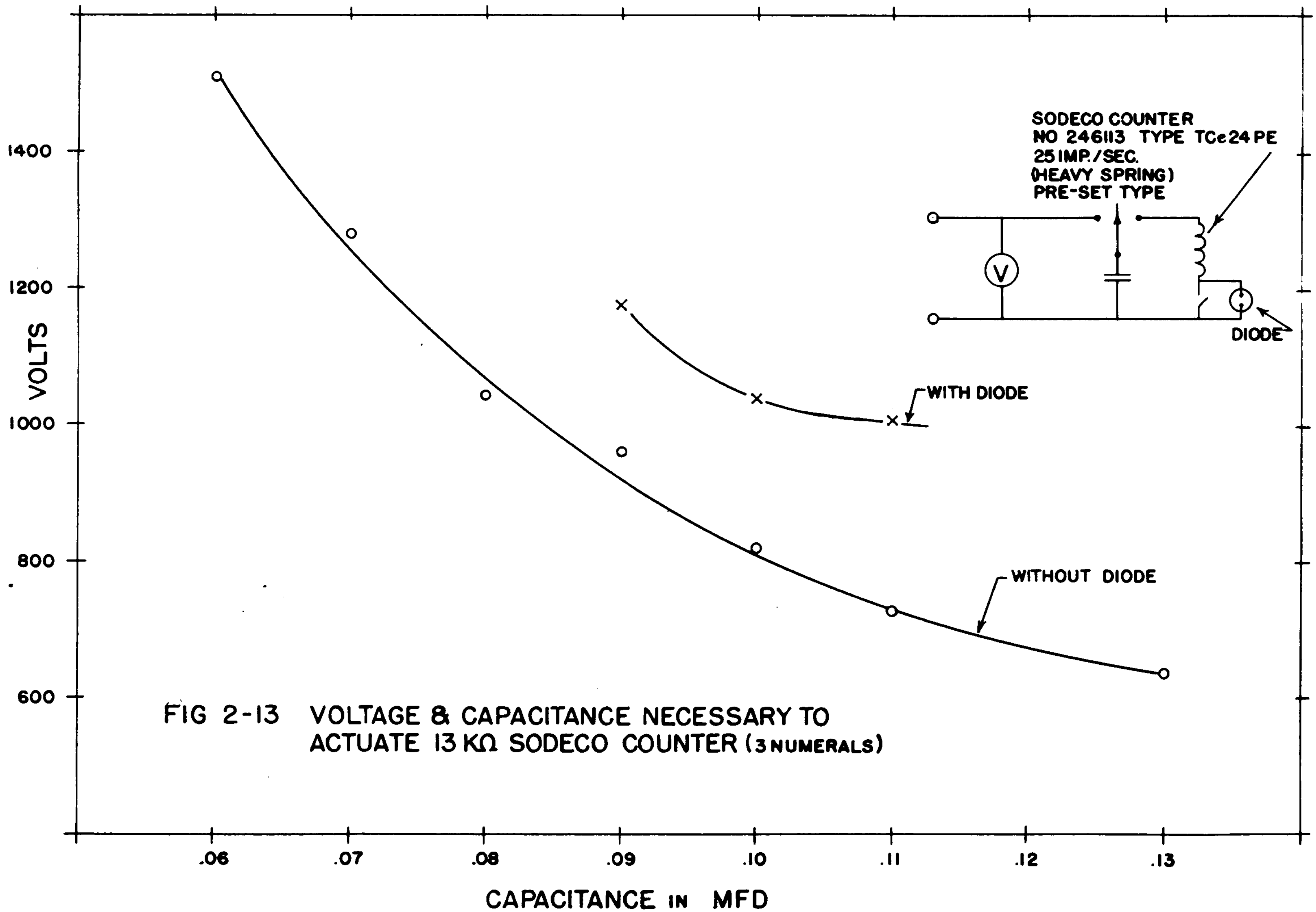


FIG 2-13 VOLTAGE & CAPACITANCE NECESSARY TO ACTUATE 13 KΩ SODECO COUNTER (3 NUMERALS)

DR. NO 586

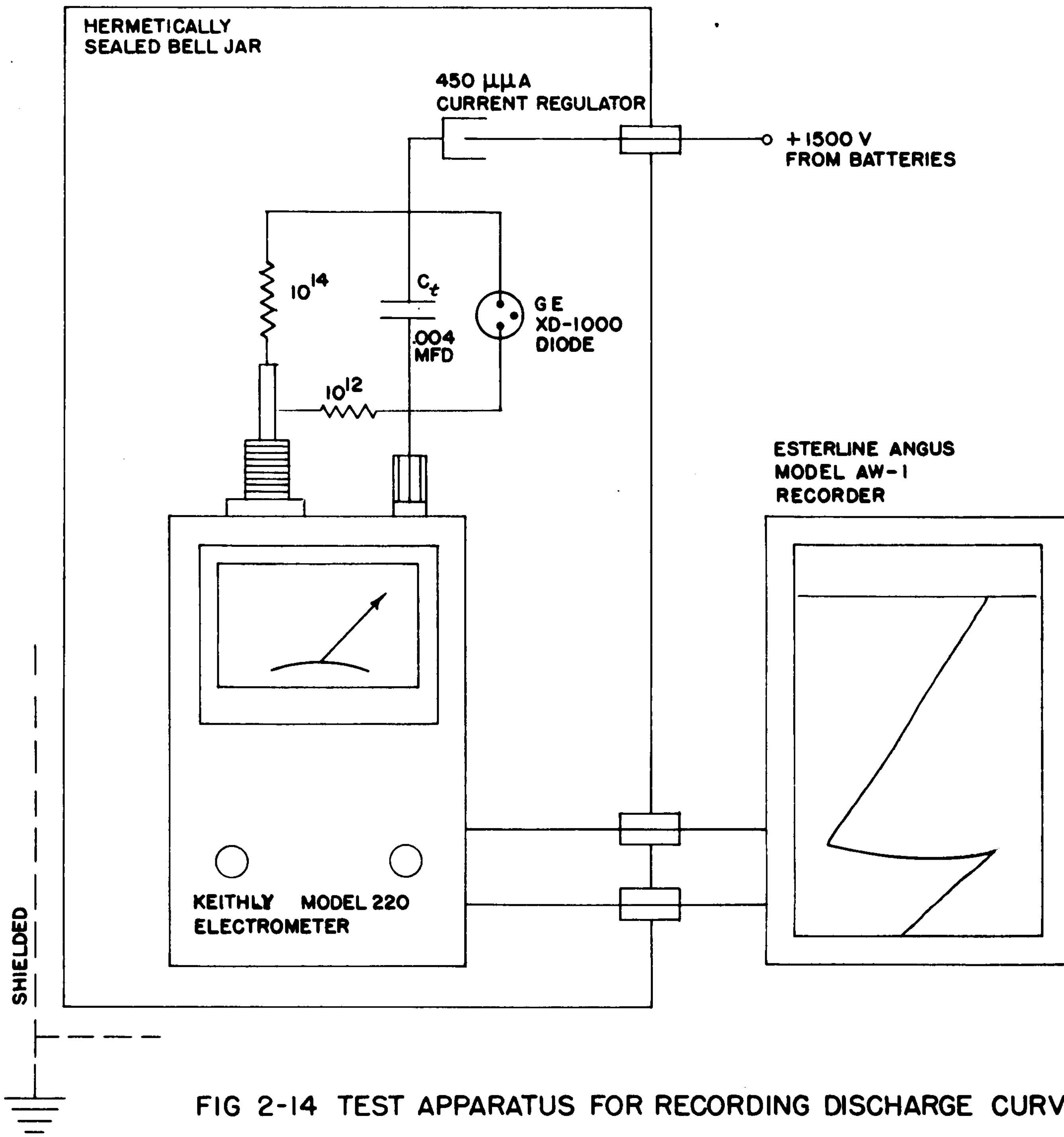
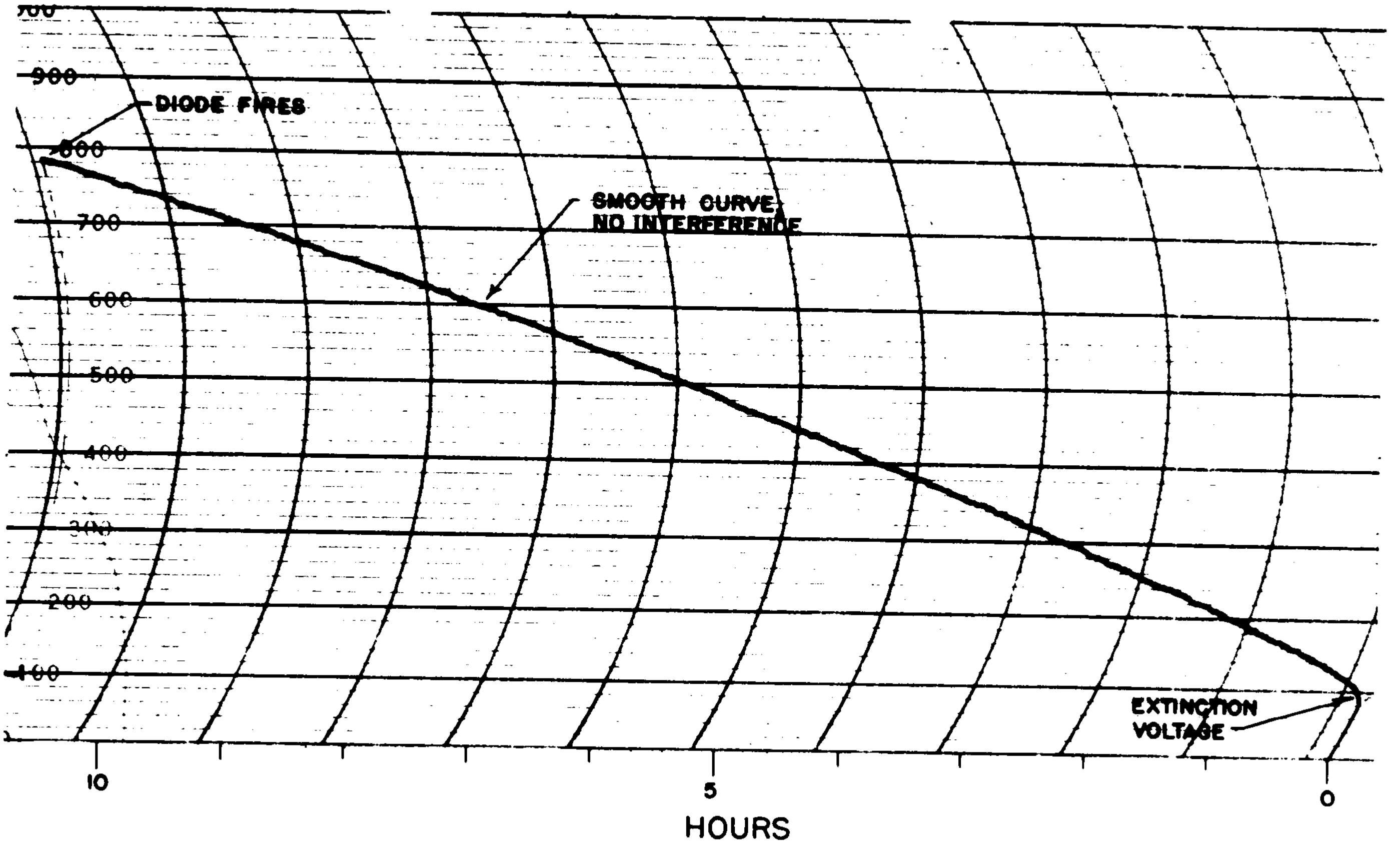


FIG 2-14 TEST APPARATUS FOR RECORDING DISCHARGE CURVE

DR.NO 587



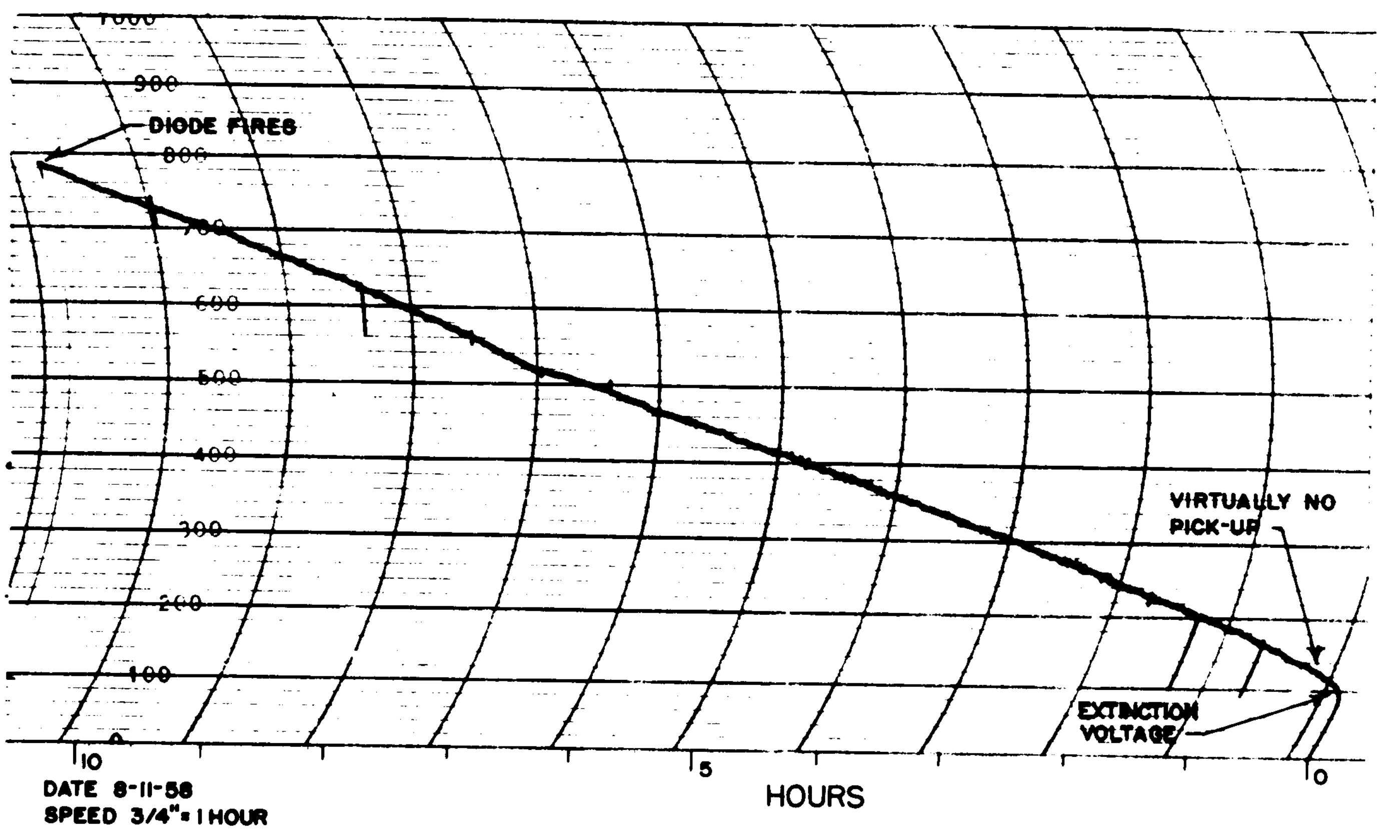


FIG 2-15 SAMPLE CURVE RECORDED FROM CIRCUIT FIG 2-14

DR. NO. 576

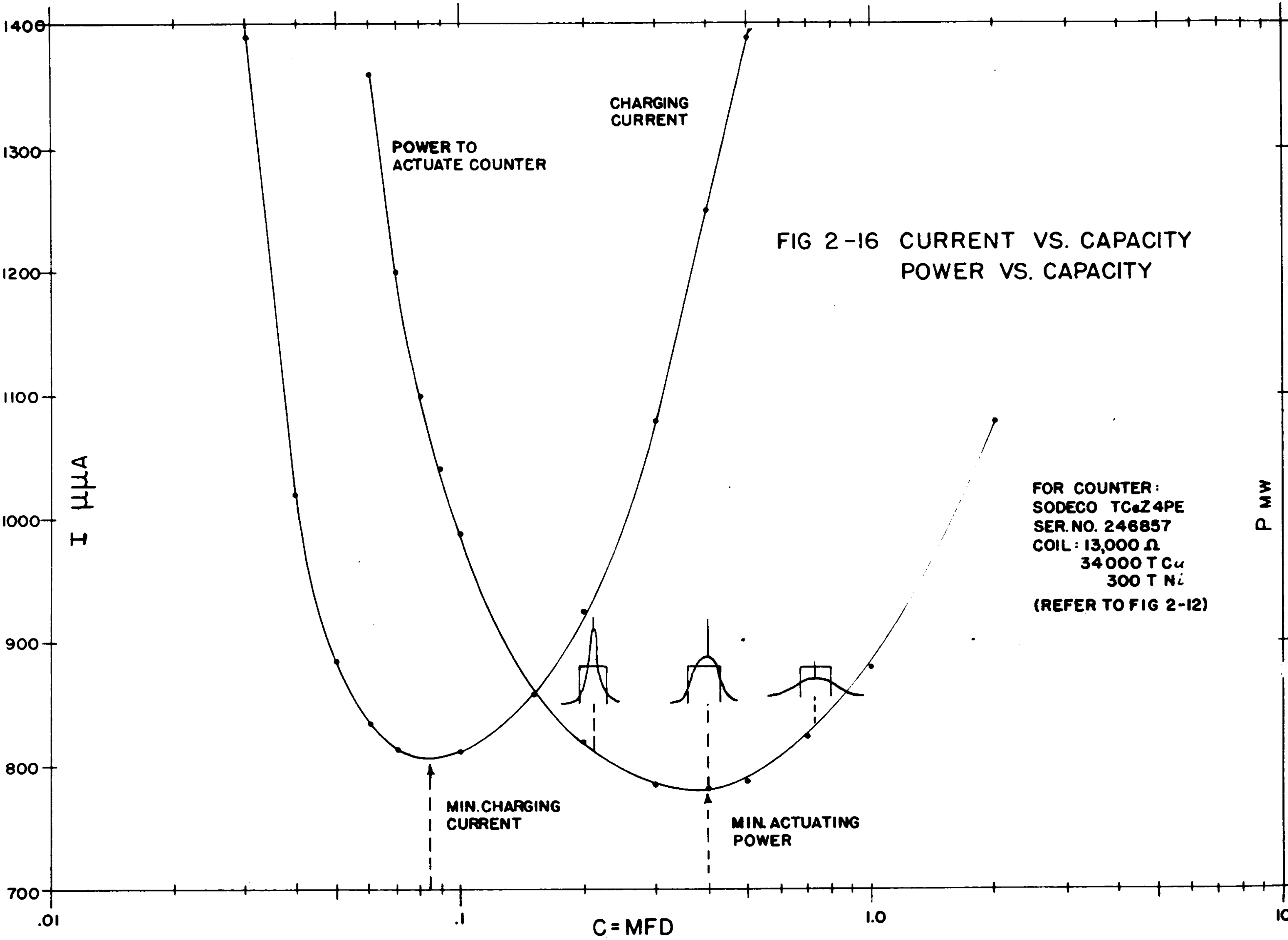


FIG 2-16 CURRENT VS. CAPACITY
POWER VS. CAPACITY

DR. NO. 588

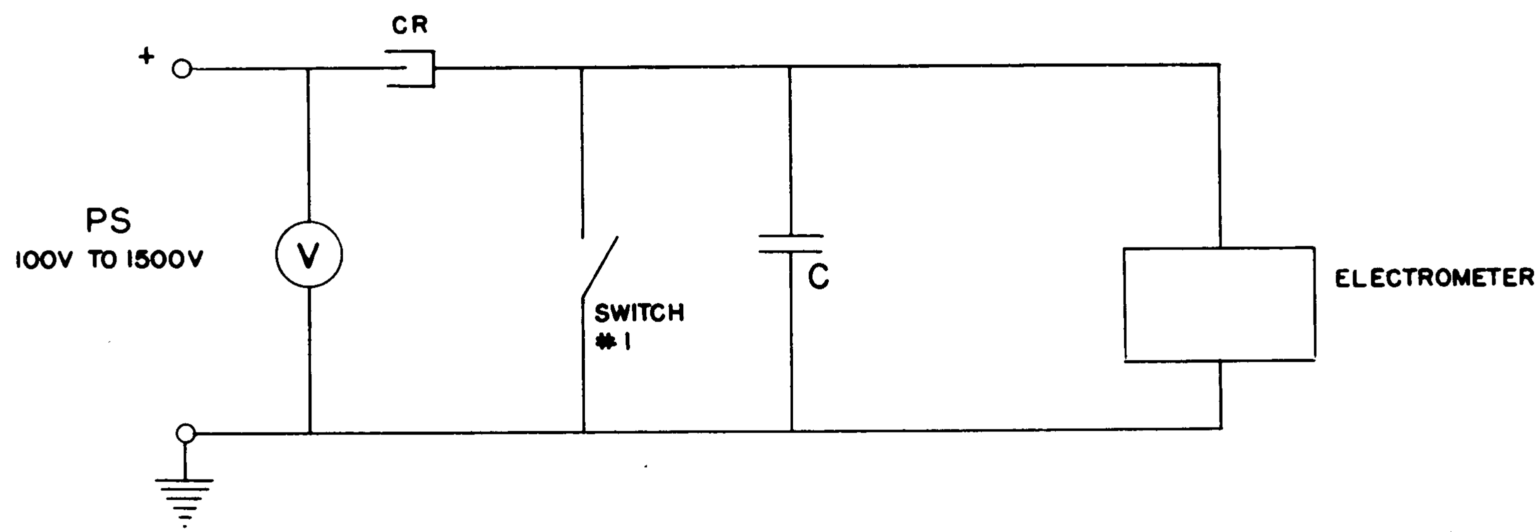


FIG 2-17 CURRENT REGULATOR TEST CIRCUIT

DR. NO. 589

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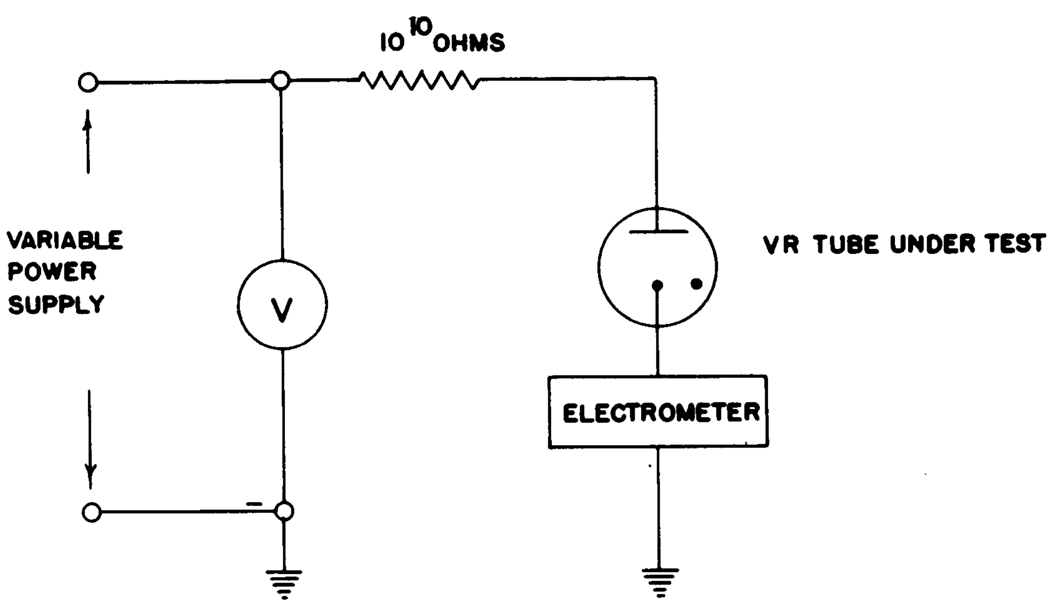

FIG 2-18 V R TUBE TEST CIRCUIT

DR. NO. 590

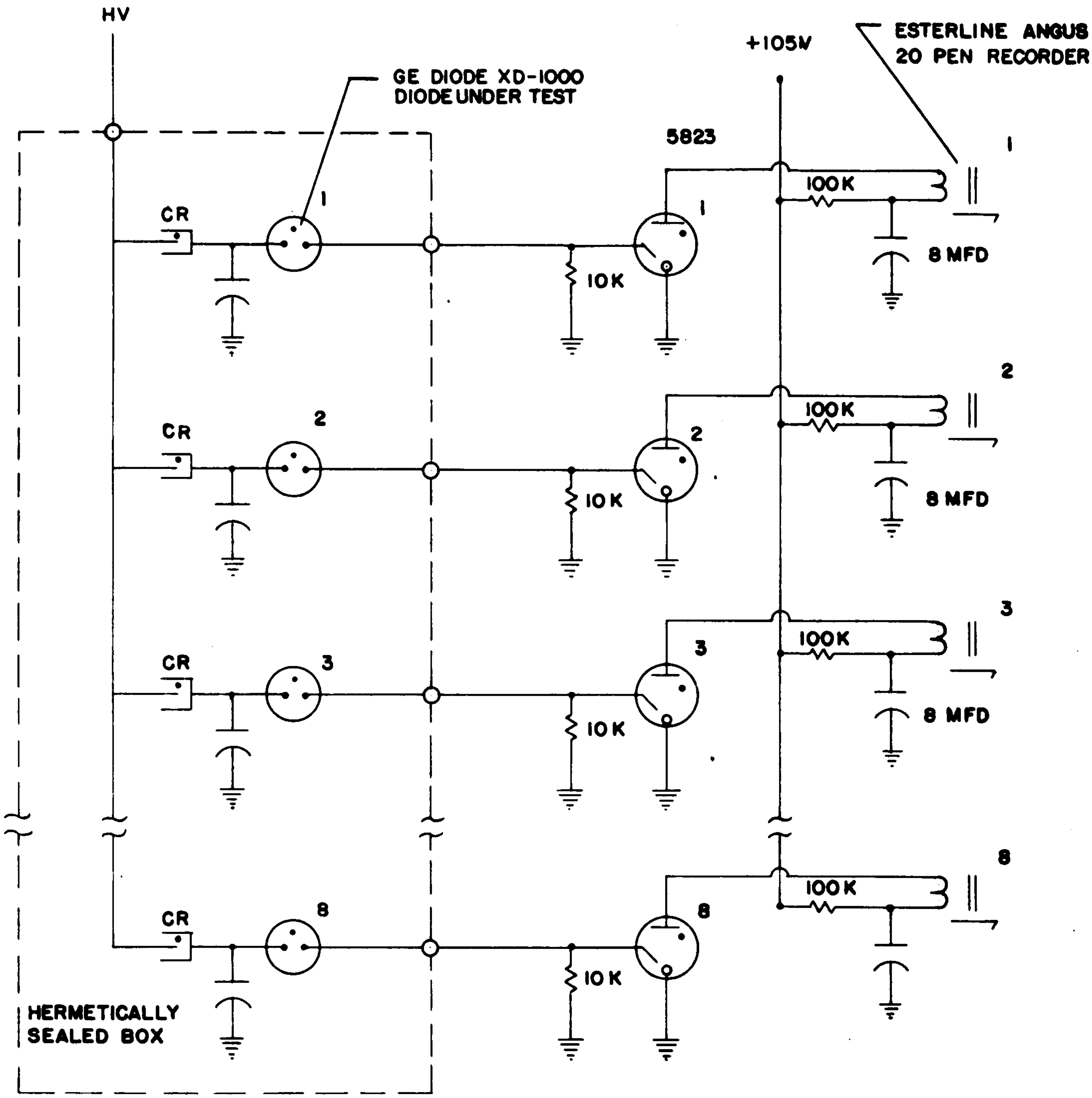

FIG 2-19 SCHEMATIC TEST SET UP FOR GAS DIODES, TESTING CONSTANCY OF CYCLE

DR. NO. 591

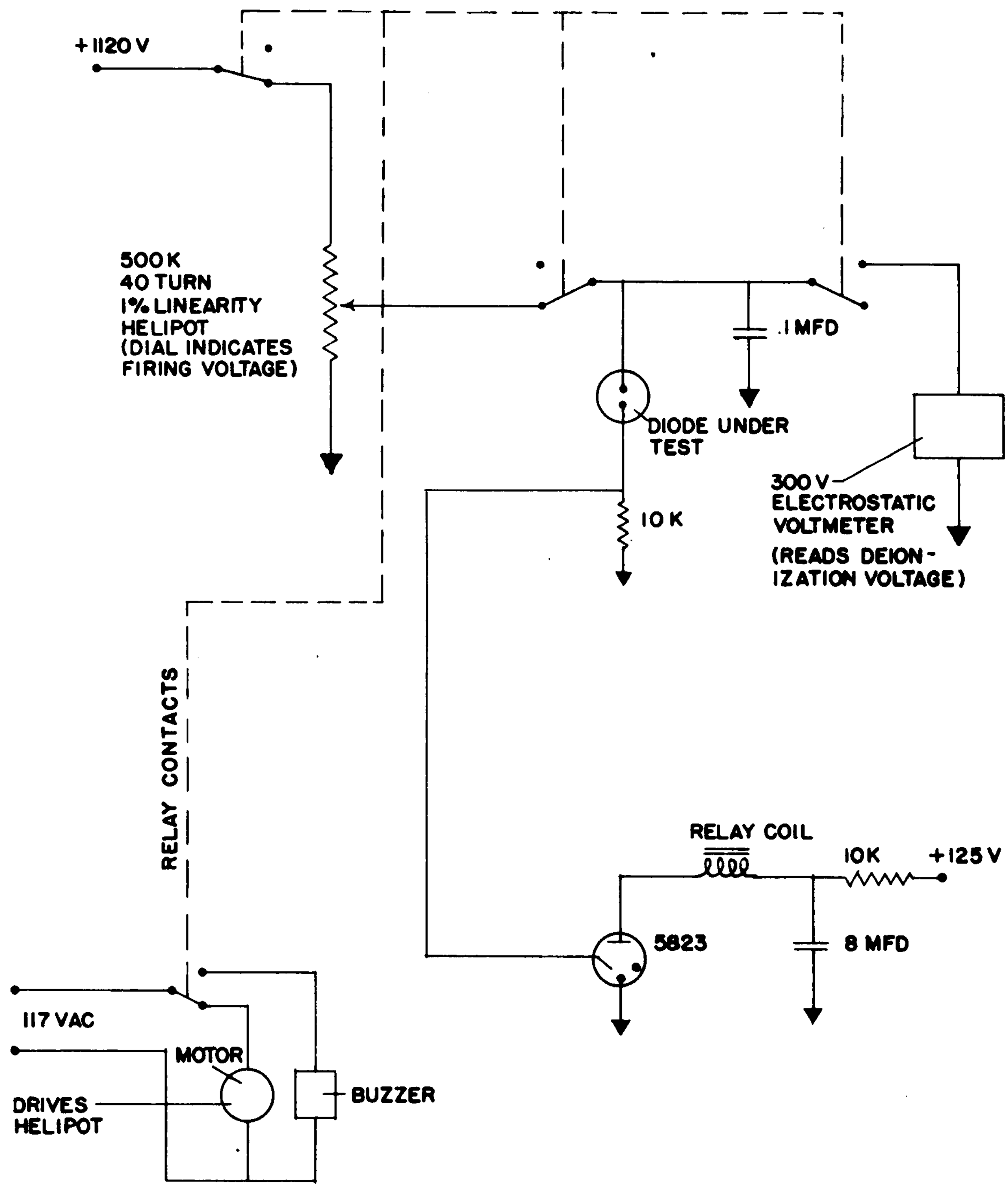

FIG 2-20 TEST APPARATUS TO MEASURE DIODE FIRING AND DEIONIZATION VOLTAGE

DR. NO 592

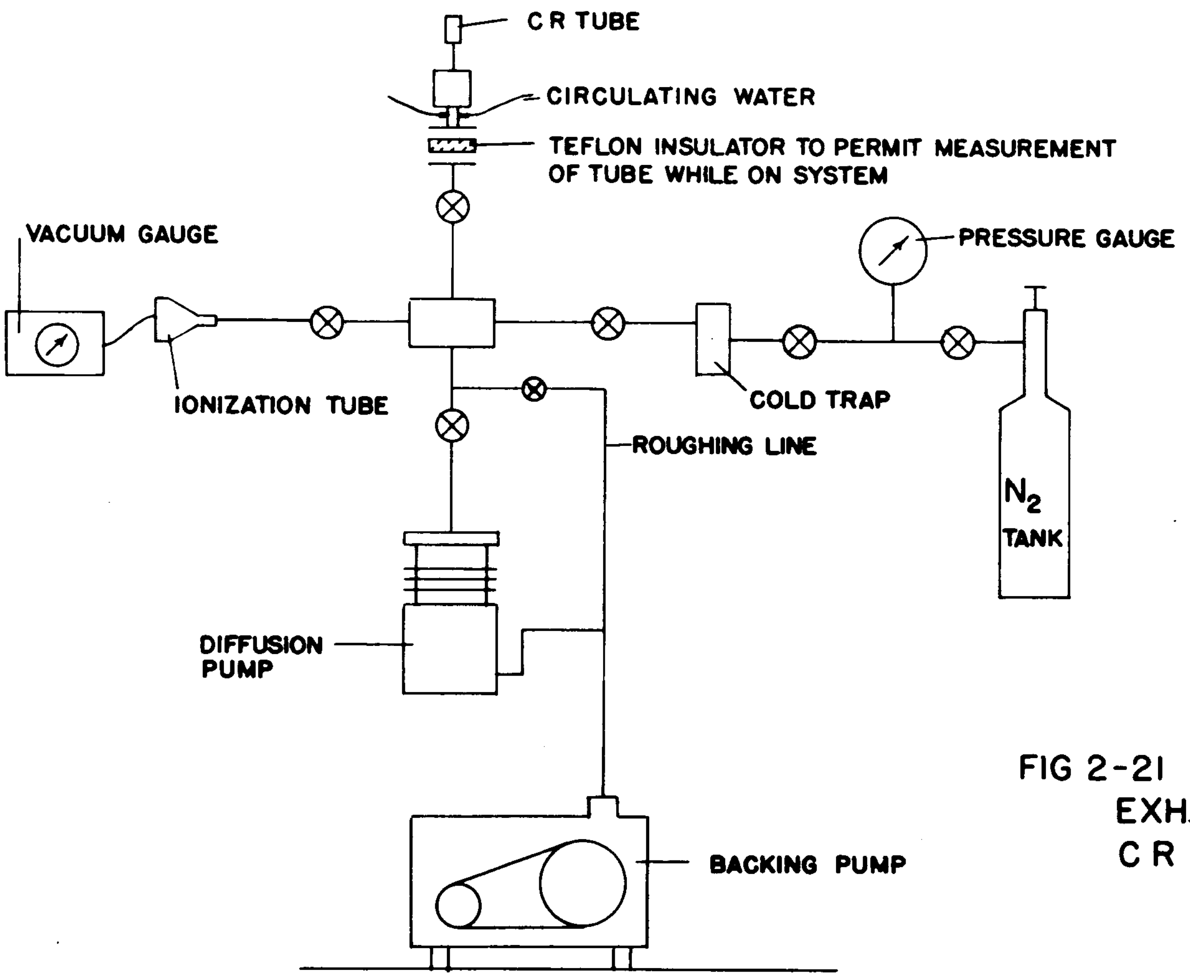

FIG 2-21 BLOCK DIAGRAM OF EXHAUST SYSTEM FOR C R TUBE

DR. NO. 593

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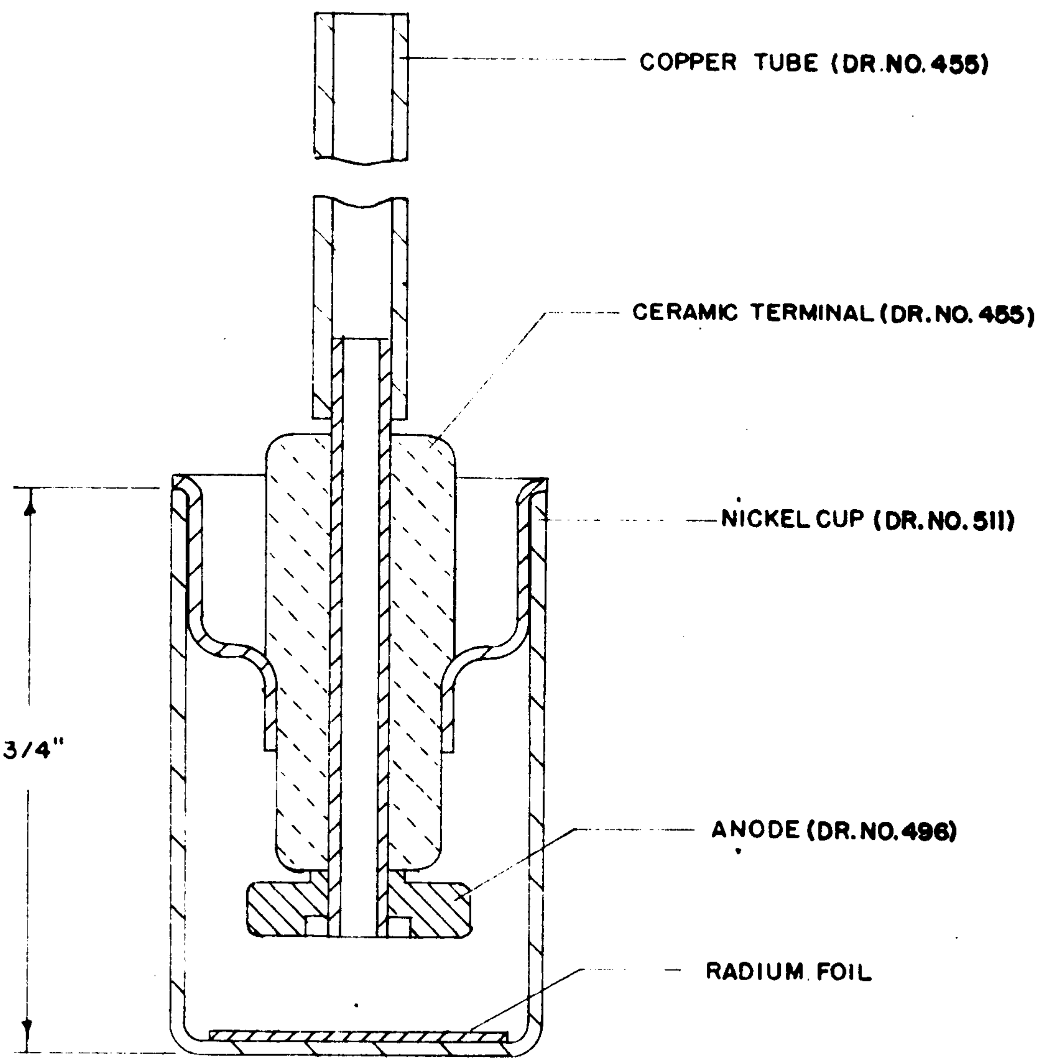
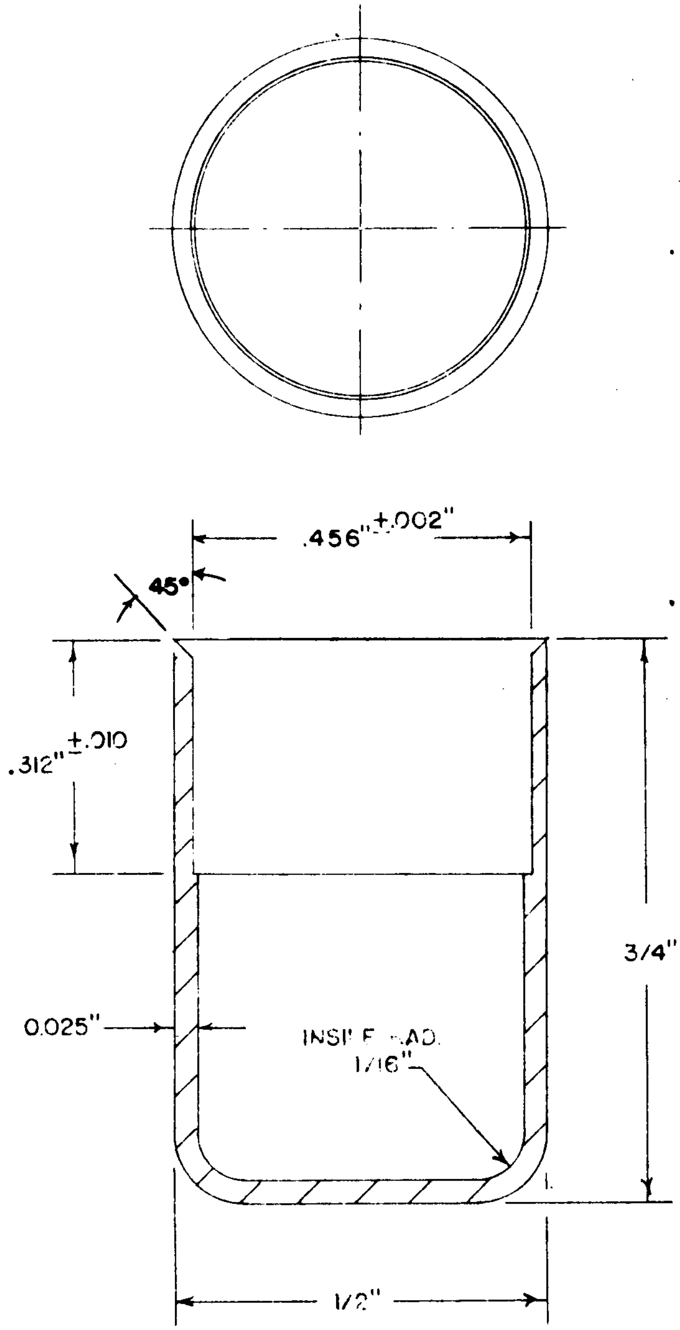


ELECTRODE SPACING .075"

FIG 2-22 CURRENT REGULATOR TUBE ASSEMBLY

SCALE 4"= 1"
DR.NO. 495
7-7-58



MATERIAL: GRADE A NICKEL

FIG 2-23 CURRENT REGULATOR ENCLOSURE

SCALE 4" = 1"
DR. NO. 511
7/28/58
REV I

BK

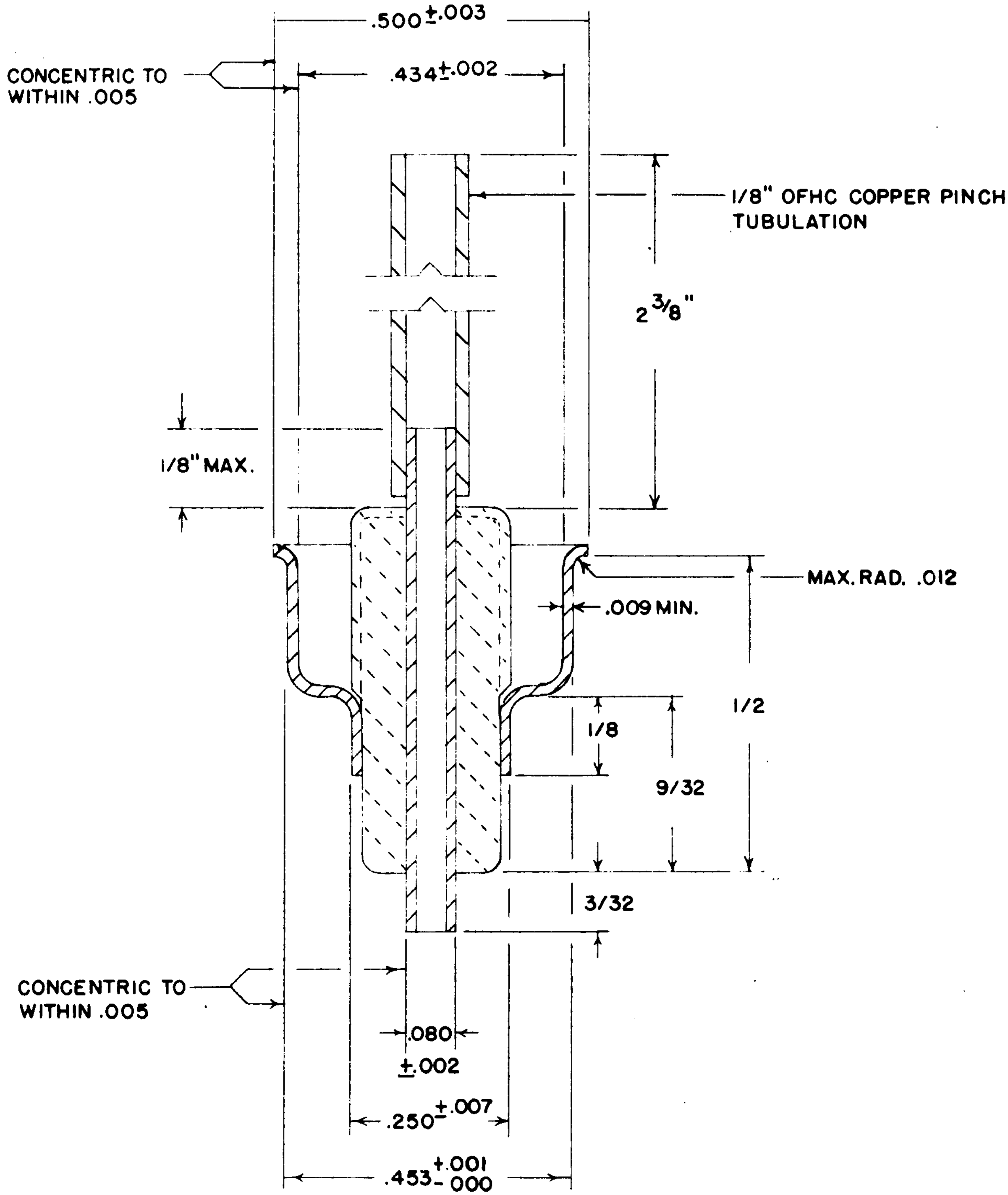
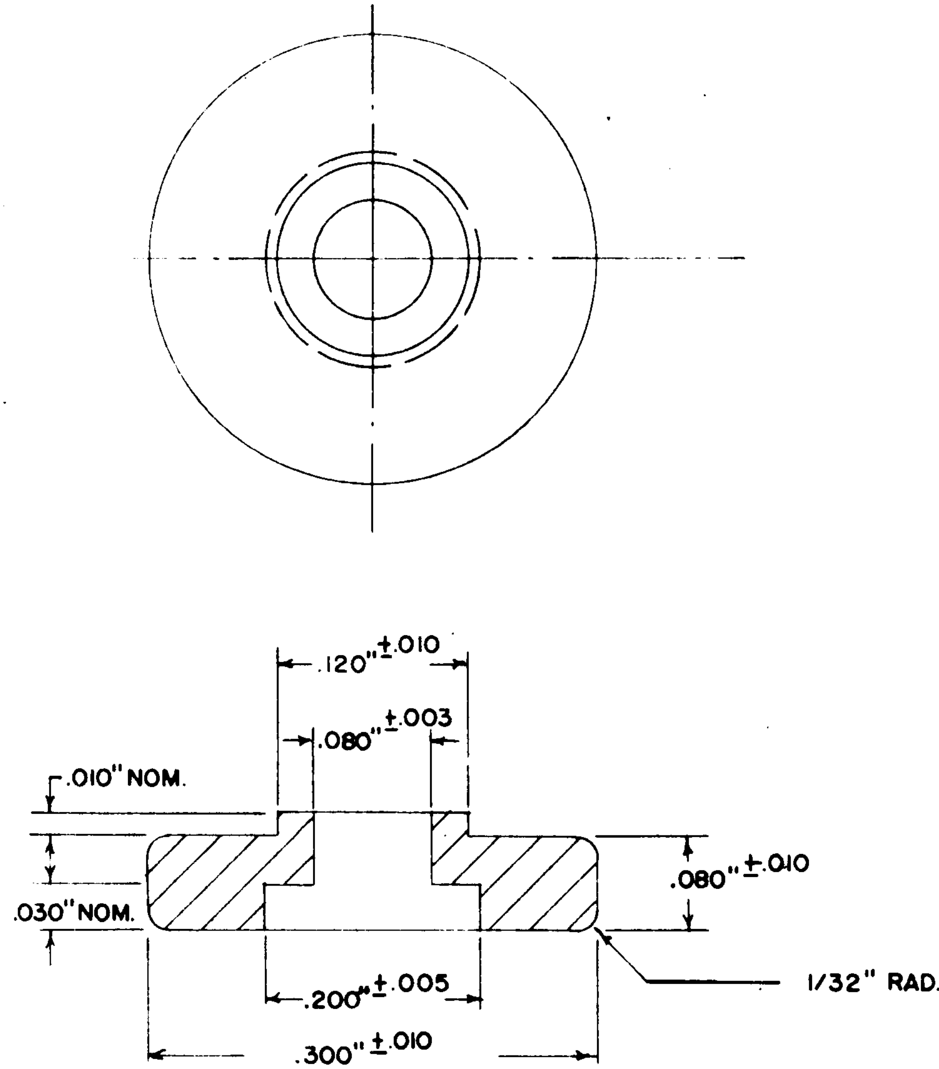


FIG 2-24

TERMINAL FOR CURRENT REGULATOR TUBE

S.T.N. ± 1/64 ± .005
SCALE 4"=1"
DR. NO. 455
5/22/58



MATERIAL : GRADE A NICKEL

FIG 2-25
ANODE FOR CURRENT REGULATOR TUBE

SCALE 8" = 1"
DR.NO. 496
7-7-58
REV 1

B.K.

DR. NO 594

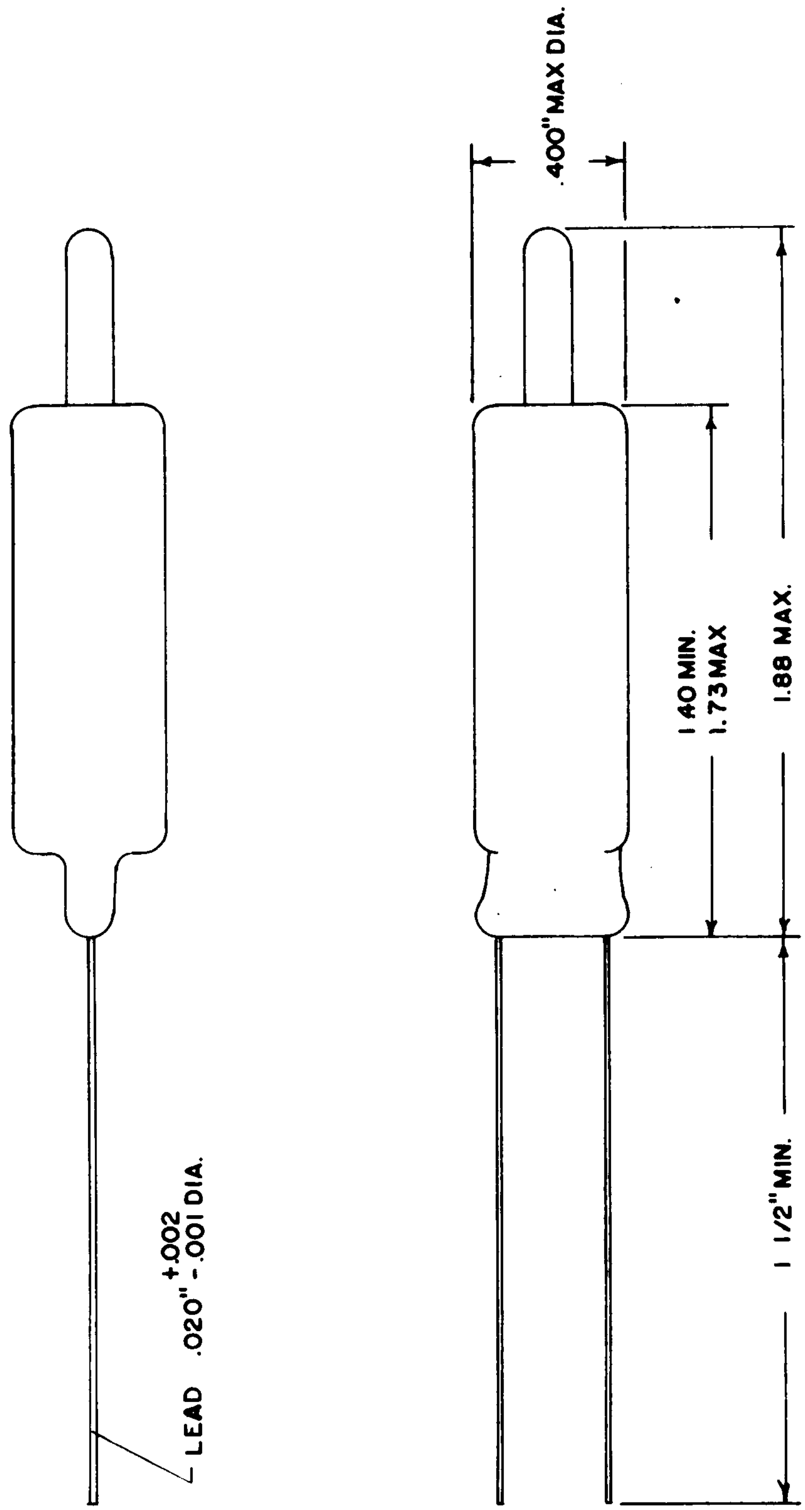


FIG 2-26 OUTLINE DRAWING OF VOLTAGE REGULATOR TUBE

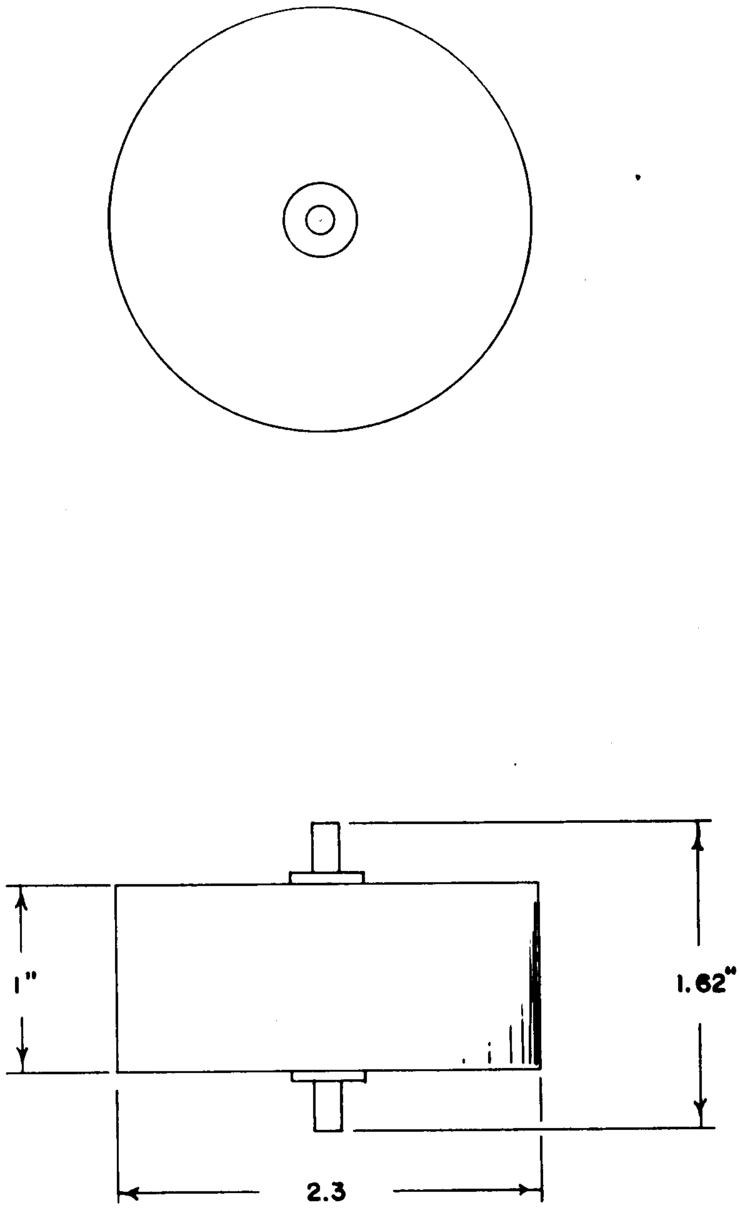


FIG 2-27 OUTLINE OF .IMFD 1000 VOLT CAPACITOR

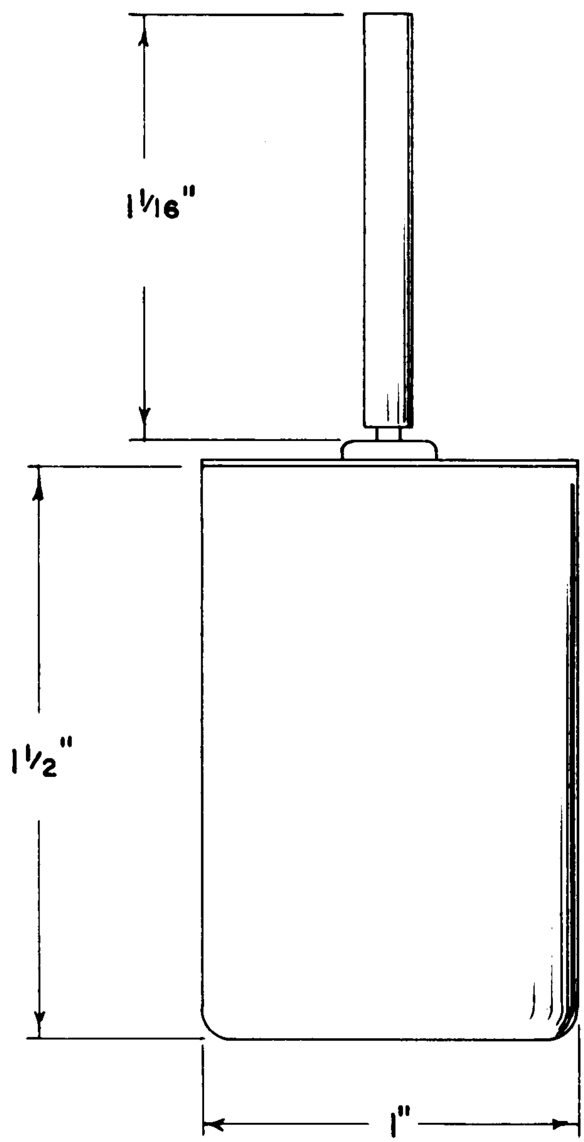


FIG 2-28 OUTLINE OF R-2 BATTERY

SCALE 2" = 1"
DRNO 596

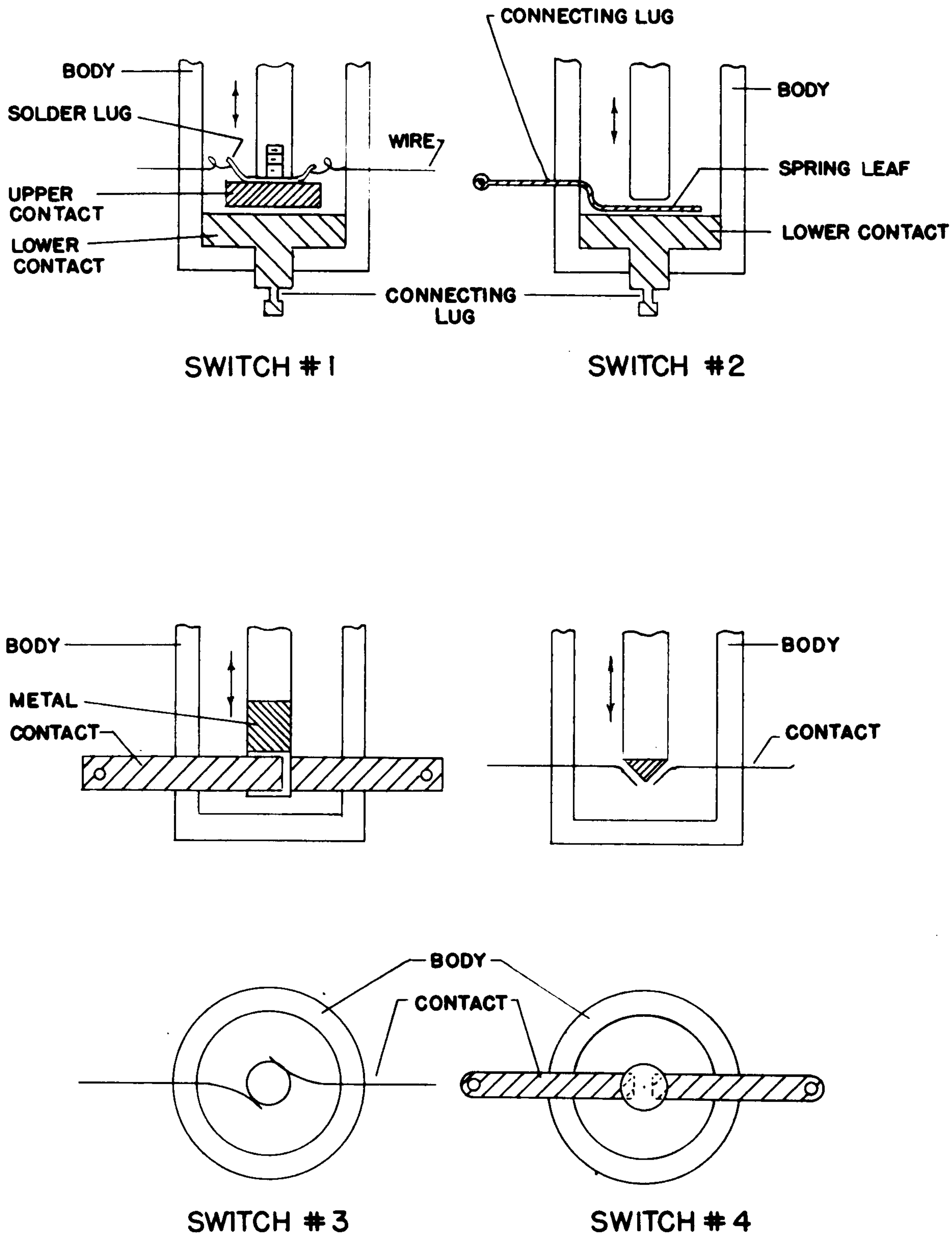


FIG 2-29 PROPOSED SWITCH DESIGNS

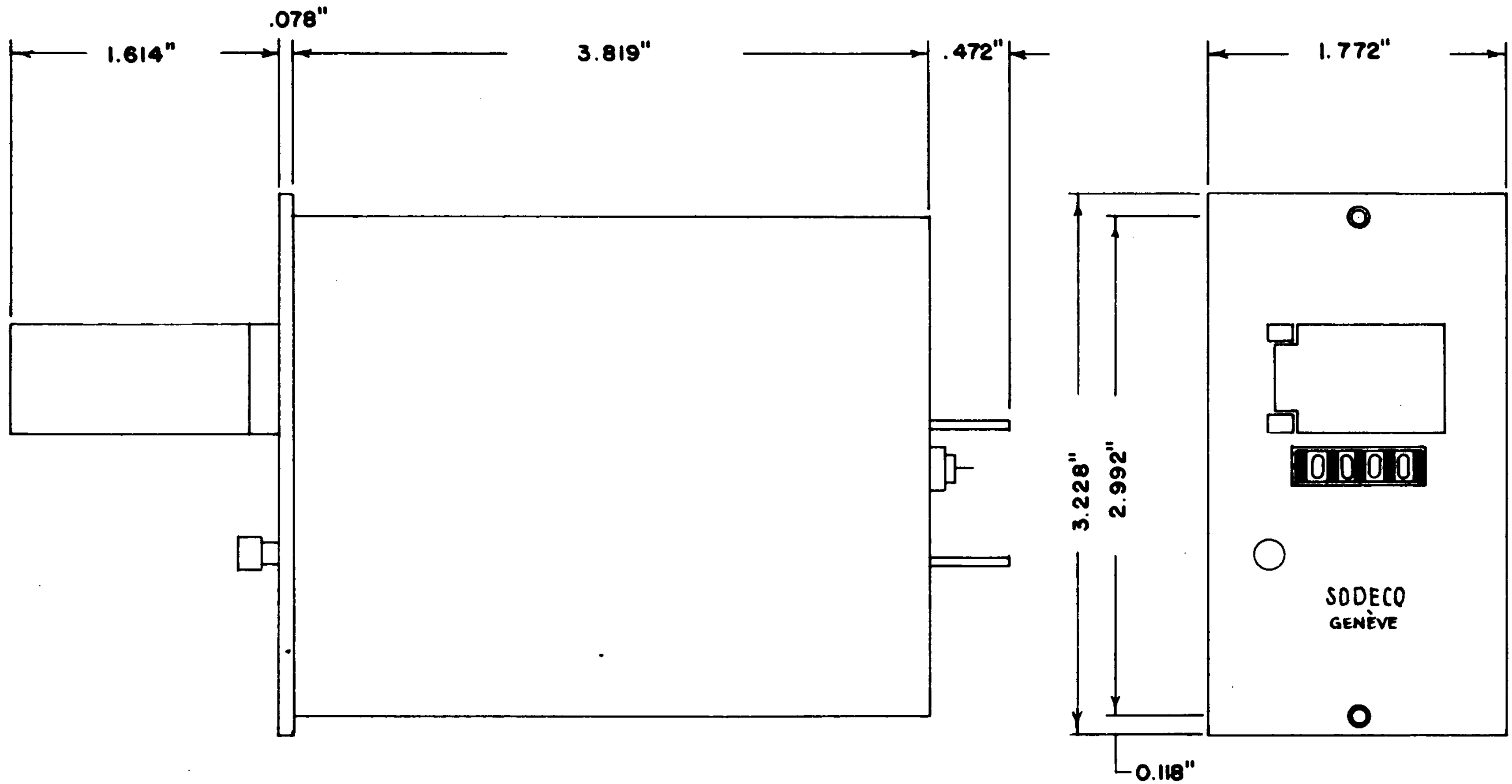


FIG 2-30 SODECO COUNTER

DR. NO. 598

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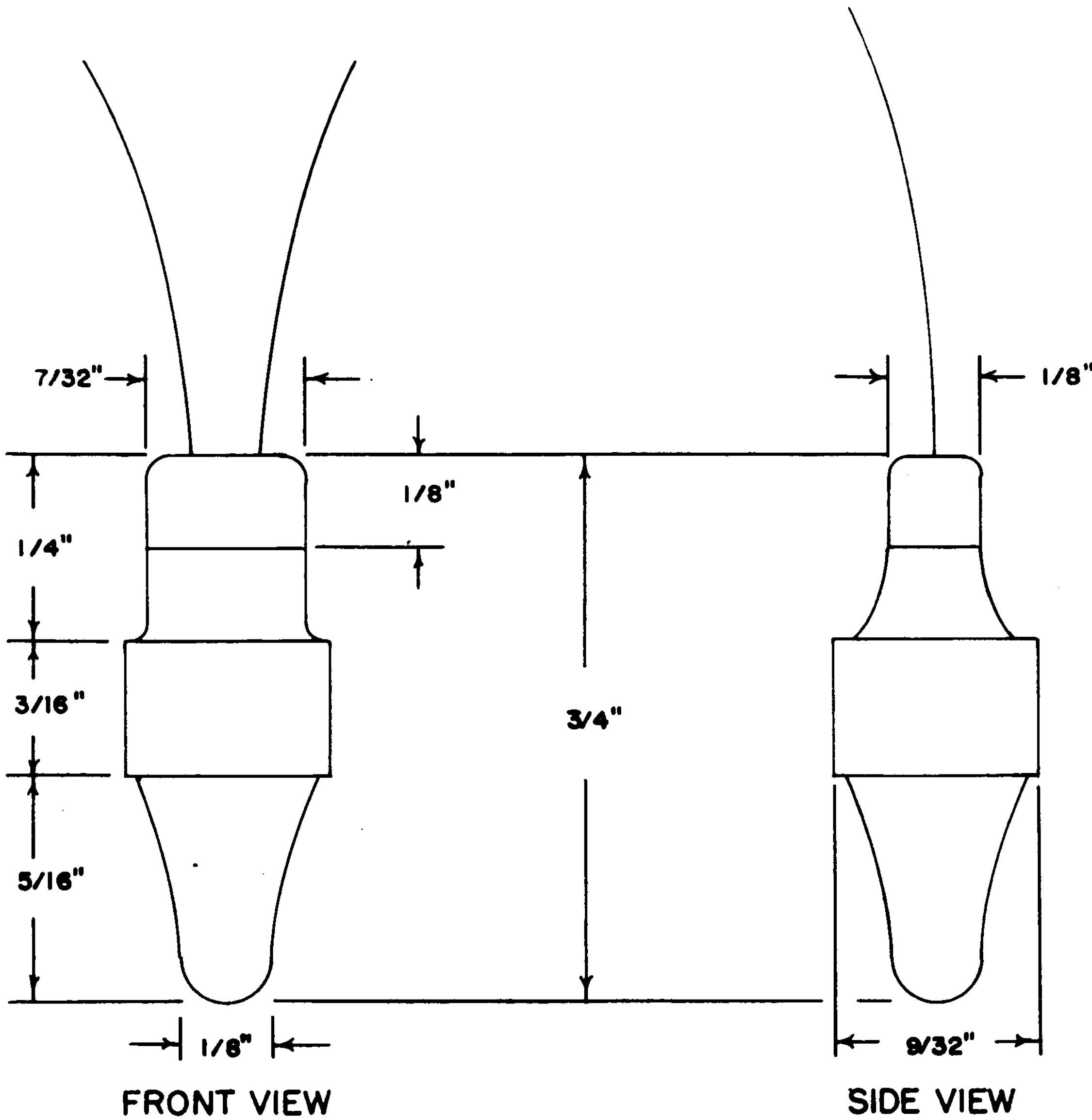

NOTE: ALL DIMENSIONS
ARE APPROXIMATE

FIG 2-31 DISCHARGE DIODE OUTLINE

DR NO 599

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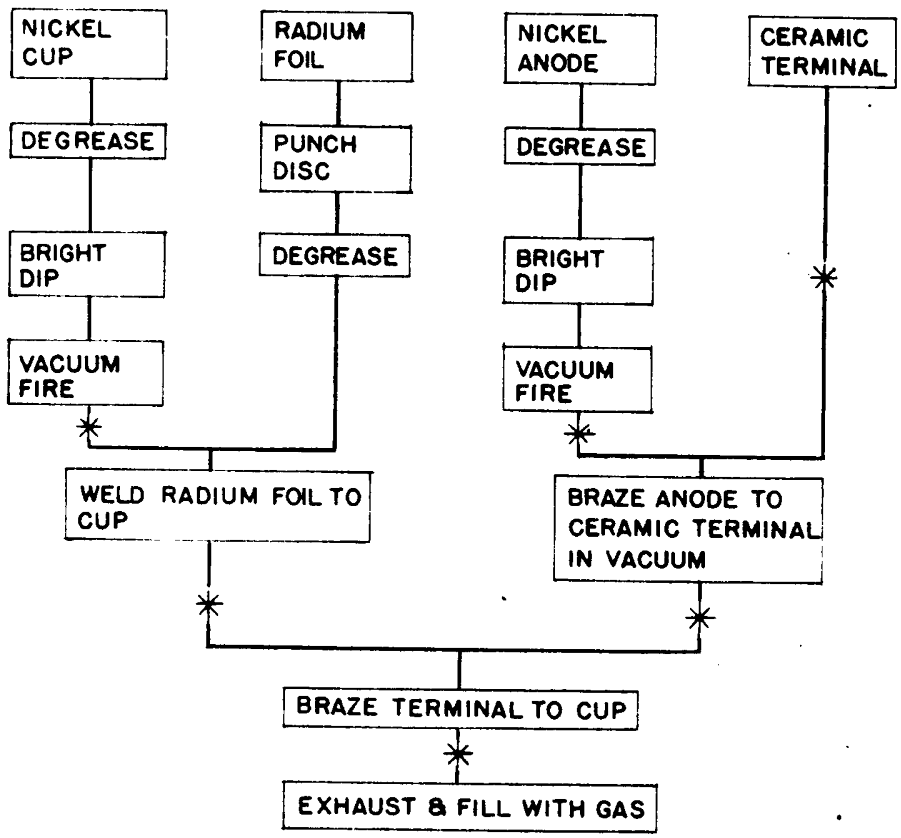
FIG 2-33 FLOW CHART FOR CURRENT REGULATOR



* WHEN NECESSARY TO STORE PARTS AT THESE POINTS, USE A DESICCANT.

DR. NO. 494
7-7-58

BK